The Analysis of *Angin Puting Beliung* Risk Rate by Utilization of Remote Sensing and Geographic Information Systems in Semarang

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Abstract

This study examines the risk rate of *Angin Puting Beliung* in Semarang of Central Java. The *Angin Puting Beliung* is a local designation for small-scale tornadoes that occur in Indonesia, originates from differences in pressure of a weather system, leads to strong winds. Between January 2014 and December 2018, the occurrence of *Angin Puting Beliung* in Semarang city of Central Java reached 91 times with a total financial loss of around IDR 852,500,000 (USD 60,000). High population densities and settlements without being followed by control of spatial use and land-use change make Semarang more at risk of being hit by a tornado. This study specifically aims to determine the level of physical, social, and economic vulnerability as well as to analyze the risk level of *Angin Puting Beliung* in Semarang city. The survey is used as the main method in this study. Samples were taken to represent the population namely land cover, slope, and land surface air temperature with data analysis using a weighted tiered quantitative method to answer the purpose of knowing the distribution of hazard and vulnerability areas and analysis of the results of mathematical calculations to determine the risk of *Angin Puting Beliung*. The results obtained show that Semarang city has a high hazard level of 28,502% which is mostly found in the southwest and northeast of Semarang. High levels of vulnerability are in the sub-districts of West Semarang, Mijen, Gunung Pati, and Tembalang. The risk level with a high class ranks the least, namely from other classes with a distribution in the sub-district of Tugu and Tembalang, accounted at 16.294%.

Keywords: tornado, disaster, danger, vulnerability, risk

1. Introduction

The data from the Indonesian Disaster Management Agency (BNPB, 2018) suggests that from 2008-2017, the *Angin Puting Beliung* disaster has become the second-highest occurrence after flood. This indicates that tornadoes are indeed occurring frequently in Indonesia. As illustrated in Figure 1, in 2018, there were 238 cases of *Angin Puting Beliung* alone in Central Java, which demonstrates the high level of exposure of the region to the disaster. Nurjani et. al (2013) states

that the cyclone disasters mostly occur in the northern and southern parts of Central Java which had a relatively smoother topography than the central part, in which one area experienced a cyclone disaster, namely Semarang city, the capital of Central Java Province.

Sub-district	Cases (2014-2018)	Injured (Persons)	Number of Deaths	Damaged Houses	Estimated Losses (IDR.000,-)
Banyumanik	4	5	0	0	10.000.000
Candisari	6	1	0	8	85.000.000
Gajah Mungkur	6	0	0	2	12.500.000
Gayamsari	1	0	0	2	0
Genuk	4	0	0	5	20.000.000
Gunung Pati	6	0	0	17	30.000.000
Mijen	1	0	0	1	0
Ngaliyan	4	2	0	1	175.000.000
Pedurungan	4	0	1	3	0
West Semarang	15	3	1	50	50.000.000
South Semarang	8	0	0	2	35.000.000

Central Semarang	3	0	0	3	150.000.000
East Semarang	7	0	0	5	0
North Semarang	6	0	0	68	25.000.000
Tembalang	12	0	0	13	160.000.000
Tugu	4	0	0	2	100.000.000
Total	91	11	2	182	852.500.000

Source: BNPB, (2018)

Semarang is an area of 373.67 km² with a density of 4,628 people/km². The city is populated by 1,729,428 people (BPS, 2018), making the place as the most densely populated city in Central Java. This density makes the Semarang population to have a higher level of vulnerability and exposure to the threat of *Angin Puting Beliung* (Fakhrurrozi et al, 2016). As shown in the Table 1 above, recorded in the span of January 2014 to December 2018, the occurrence of *Angin Puting Beliung* in Semarang reached 91 times with a total financial loss amounted at IDR 852,500,000, equivalent to about USD 60,000.

Therefore, the importance of risk analysis of the *Angin Puting Beliung* disaster in Semarang is due to the city's high population density, intensive use of infrastructure, and the development of industrial and business groundwork. Without being followed by spatial use control and land use change, Semarang city is at risk of the tornado disaster. In fact, the increasing population will affect changes in land use (Nurjani et al, 2013).

Moreover, if mitigation measures are not carried out by the government or the local community, Semarang will be more at risk of being hit by a tornado. Handoko et. al (2017) states that the most important aspect in disaster mitigation is the assessment of the vulnerability in disaster-prone areas and the method that can be used in the assessment is a combination of the Remote Sensing and the Geographic Information System (GIS) methods. The GIS is able to provide geospatial data information such as objects on the surface of the earth quickly, while providing an accurate spatial analysis system will be beneficial in analyzing disaster risk (Faizana et al, 2015). Currently, research on tornado risk is still rarely done in both national or local level, including at Semarang. One reason was due to the lack of competent resources in their fields (BPBD Semarang, 2018). We argue that studying *Angin Puting Beliung* disaster risk in Semarang City will facilitate the public to learn about disaster risk studies in their own

zone. The area affected by the disaster, the number of people exposed to the disaster, the potential loss caused by the disaster, and the capacity it has to reduce the risk of the disaster are some of the important aspects that the public need to know. Consequently, impacts caused by disasters that potentially occur in the future can be minimized, because the community are aware and have adequate knowledge on disaster preparedness and mitigation. Based on the results of this disaster risk analysis, it is expected that the implementation of disaster management will be more effective.

2. Research Method

The site of this research is Semarang city, which has the coordinates of the Most Placed at positions 6° 50'- 7° 10'South Latitude and 109° 35'- 110° 50 'East Longitude with the administrative boundaries of Semarang as follow:

- a. Northern Boundary: Java Sea
- b. Southern Boundary: Semarang Regency
- c. Eastern Boundary: Demak Regency
- d. Western Boundary: Kendal Regency

Administratively, Semarang is divided into 16 sub-districts and 177 villages. Of the 16 existing sub-districts, the largest area is the Mijen sub-district, at 57,967 km². The smallest area is Central Semarang sub-district, with a width of 5,360 km². Along with the development of the city, Semarang was developed as a city that focuses on trade and services. Based on its location, the trade and service area are widespread and generally located along major roads, modern trade areas, especially in the Simpanglima area, which is known as the economic pulse of Semarang. More details on the number of villages and total area in km² is shown in the Table 2 below.

No	Sub-districts	Total of Urban Village	Total Area (Km2)
1	Banyumanik	11	31,039
2	Candisari	7	6,537
3	Gajah Mungkur	8	9,712
4	Gayamsari	7	6,285
5	Genuk	13	26,697
6	Gunung Pati	16	59,750
7	Mijen	14	57,967
8	Ngaliyan	10	44,527

9	Pedurungan	12	22,177
10	West Semarang	16	22,675
11	South Semarang	10	6,171
12	Central Semarang	15	5,360
13	East Semarang	10	5,628
14	North Semarang	9	11,314
15	Tembalang	12	40,249
16	Tugu	7	29,793

Source: BPS Semarang (2018)

2.1 Data and Data Collection Methods

In this study, we use both primary and secondary data. Primary data is obtained directly by conducting data processing, direct measurement, and interviews. The secondary data is obtained from the relevant agencies. More details as follow:

1. Primary Data

Primary data in the form of SRTM image data obtained through the USGS website by selecting the Semarang city study area. The SRTM imagery is used to create a slope map parameter by performing image processing. Other primary data can be found in the Landsat 8 OLI Image of the Semarang study area from the USGS. Landsat 8 OLI imagery is used to create surface air temperature parameters by image processing.

2. Secondary Data

Secondary data in this study include spatial data as listed in Table 2.1 as follows:

No	Data	Format	Source	Characteristics
1.	Administration Map of Semarang.	Digital/ Vector Data	BAPPEDA Semarang	Scale 1:25.000, (Year) 2001
2.	Used Land Map of Semarang city.	Digital/ Vector Data	BAPPEDA Semarang	Scale 1:25.000, (Year) 2011-2031
3.	Spot-6 Image Semarang City 25 March 2016.	Digital/ Raster Data	Ministry of of Public Works and Public Housing (PUPR)	Multi Spatial Resolution (6m), <i>pankro</i> (1,5m), <i>pansharpening</i> , <i>ortho</i> Processing Level

4.	Annual Rainfall Data of Semarang.	Digital/ Tabular Data	BMKG	(Year) 2014-2018
5.	<i>SRTM (Shuttle Radar Topographic Mission) 1 Arc-second</i> Data of Semarang city.	Digital/ Raster Data	USGS	Spatial Resolution 30m, Version 3
6.	Semarang city (in number)	Digital	BPS	(Year) 2018
7.	Number of Sub-districts in Semarang	Digital	BPS	16 Sub-districts (year) 2018
8.	Economic Indicator of Semarang city	Digital	BPS	(Year) 2017
9.	Disaster Capacity Level Data of Semarang city	Digital/ Tabular Data	BPBD	(Year) 2017
10.	Recapitulation Location data of <i>Angin Puting Beliung</i> Disaster in Semarang.	Digital/ Tabular Data	BPBD	(Year) 2014-2018
11.	Data of Landsat image 8 OLI TIRS, (Year) 2017	Digital/ Raster Data	USGS	Spatial Resolution OLI (30m), TIR (100m), Process Level L1T

Meanwhile, the instruments used in this research include:

1. A set of laptops for processing research activities
2. ArcMap 10.1 software for processing and presenting spatial data
3. Microsoft Office for the preparation of tabular data and research reports
4. PDF Maps plotting software for field sampling locations
5. Camera for field survey documentation
6. Field checklist table to help field survey notes
7. Infrared Thermometer for temperature sampling in the field
8. Clinometer for slope sampling in the field

2.2 Method of Analysis

The research method used is a survey with data collection techniques carried out from population sampling. Samples are taken to represent the population. The parameters used in this study are the hazard parameters consisting of land cover, slope, rainfall, and surface air temperature. The parameters of vulnerability include physical, social, and economic

vulnerability and added with the regional capacity parameters which from the results of the three parameters then analyzed to be a risk of *Angin Puting Beliung*.

This study will examine several variables that are the focus of research on *Angin Puting Beliung* disasters in Semarang. There are 4 variables that will be the focus, namely danger/vulnerability, vulnerability, capacity and risk. The variables used as input have been selected based on literature review, and taking into account the availability of data at relevant agencies.

The preparation of a hazard map is one of the important processes in determining the risk assessment of *Angin Puting Beliung* disaster. The hazard map contains four parameters, namely a land cover map, rainfall map, surface air temperature map and slope map. All four parameters are overlaid, then scaling and welding are carried out using the AHP method according to the influence caused by *Angin Puting Beliung* hazard, and combined with *Angin Puting Beliung* disaster data that occurs as a validation unit for *Angin Puting Beliung* disaster map (Figure 1).

Figure 1. Hazard Parameter Flow Chart

The *Angin Puting Beliung* disaster vulnerability map has several parameters in which there are indicators such as social vulnerability (population density and vulnerable groups), physical vulnerability (number of permanent buildings, number of semi-permanent buildings, and number of non-permanent buildings), and economic vulnerability (area of productive land and GRDP contribution). Each of these parameters is entered into a table and weighted using the AHP according to the effect caused by the vulnerability of *Angin Puting Beliung*. Furthermore,

the results of the table are loaded into the Semarang City administration map according to the administrative area of each vulnerability study (Figure 2).

Figure 2. Vulnerability Parameters Flow Chart

Data on the level of disaster capacity in Semarang was obtained from the latest survey conducted by the BPBD Semarang in 2017. The survey included indicators such as level of disaster socialization, access to evacuation routes, and the availability of supporting equipment in dealing with disasters that can occur. In this case, the results of the survey are summarized into the level of disaster capacity in Semarang which is divided into three; low, medium and high. Flow chart of the capacity level map can be seen in the Figure 3.

Figure 3. Capacity Parameter Flow Chart

Determination of disaster risk mapping is performed by combining the value of hazard, vulnerability, and capacity as in Figure 4. This process is carried out using spatial calculations to produce risk maps, which is also divided into three as shown in the Figure 4.

Figure 4. Risk Mapping Flow Chart

Data analysis methods used in this study are as follows:

- a. Data analysis method for the level of *Angin Puting Beliung* danger: weighted tiered quantitative analysis using the Analytical Hierarchy Process with overlapping fungi/overlay on each parameter. This is done by scaling and weighting on each parameter of the *Angin Puting Beliung* hazard.
- b. Data analysis method for the level of vulnerability of *Angin Puting Beliung*: weighted tiered quantitative analysis using the Analytical Hierarchy Process with overlapping fungi/overlay on each parameter by scaling and weighting on each vulnerability parameter.
- c. The method of analyzing risk level data of *Angin Puting Beliung* disaster: Uses a mathematical calculation method with the formula of $\text{Risk} = \text{Hazard} \times \text{Vulnerability/Capacity}$.

Data analysis was performed to solve the problem formulation and answer the research objectives. The results of the study are in the form of *Angin Puting Beliung* hazard map, *Angin Puting Beliung* disaster vulnerability map, and *Angin Puting Beliung* disaster risk map in Semarang.

3. Results and Discussion

3.1 Research Results

The results (Figure 5) show that Semarang overall has a medium danger level of *Angin Puting Beliung*, with an area of 261,471 km² or 67,878%. 109,793 km² or 28,502% of Semarang has the high level of danger. It is mostly located in the southwest and northeast direction precisely in parts of Ngaliyan, Mijen, Gunung Pati, Banyumanik, Tembalang, West Semarang, Central Semarang, North Semarang, South Semarang, Semarang East, Pedurungan, Genuk, and Gayamsari which are indeed areas with settlement land cover and built land despite low rainfall in the northeast, but the area has a morphology that is flat with high temperatures. However, the area has a flat morphology with high temperatures. Whereas in the low hazard class with an area of 13,944 Km² or 3,620%, it has relatively low rainfall and the land use is more vegetated with high density such as forests and gardens/plantations. The air temperature in the low area is not high with morphology from a bit steep to very steep.

Figure 5. *Angin Puting Beliung* Risk Level Map

In terms of vulnerability distribution analysis in Semarang, our findings reveal that out of the 16 sub-districts located in Semarang City, four sub-districts have high level of vulnerability. These are West Semarang, Mijen, Gunung Pati, and Tembalang. This is because the four sub-districts have high economic vulnerability due to the small amount of productive land, especially in the sub-district of West Semarang. Later it was found that the physical and social vulnerability was classified as high because the four sub-districts have high population and vulnerable groups. This is the case especially in the sub-districts of West Semarang and

Tembalang with a population of 171,000 individuals and a large number of non-permanent buildings, reaching 4,000. The four sub-districts are inversely proportional to six other sub-districts such as Tugu, East Semarang, Gayamsari, South Semarang, Candisari, and Gajah Mungkur, which get a low grade for their vulnerability. Despite the high level of social vulnerability for its density, the economic and physical vulnerability in these areas is relatively low. These six regions have a small productive land area and there are not many permanent buildings. While the rest are medium classes which consist of Ngaliyan, Banyumanik, North Semarang, Central Semarang, Genuk, and Pedurungan sub-districts. The full distribution of vulnerability levels can be seen in Figure 6. It should be noted that the level of vulnerability in an area can change to be lower or higher than before depending on the effort by the community and local government to reduce the level of disaster risk in their respective area.

Figure 6. *Angin Puting Beliung* Vulnerability Level Map

Next, disaster capacity. Two sub-districts of Semarang have a low capacity level, namely Tugu and Tembalang sub-districts. The explanation is that the two sub-districts are classified as lacking resilience, both from the community and the local government due to minimum effort to reduce the risk level of disasters that may occur. The high level of disaster capacity is found in six sub-districts of Semarang namely Mijen, Banyumanik, Candisari, South Semarang, Central Semarang, and East Semarang sub-districts. In other words, this indicates a good level of resilience in terms of the community and local government's effort to reduce the risk level of disasters. Similar to the previous category, the level of capacity in an area can also vary to be lower or higher, depending on the community and the local government. More can be seen in Figure 7.

Figure 7. Disaster Capacity Level Map

Meanwhile, in terms of disaster risk mapping, our study shows that an area of 195,425 Km² or 50,732% has a low risk of the *Angin Puting Beliung*. The high-risk of Semarang is accounted for at an area of 62.765 Km² or 16.294% of the city. The medium risk is almost double that of the high-risk Semarang. It means that half of the area is quite prone to the disaster.

Table 2. Extent of Disaster Risk

No	Sub-districts	Extent of Risk (Km ²)			Total
		Low	Medium	High	
1	Banyumanik	30,987	0	0	30,987
2	Candisari	6,537	0	0	6,537
3	Gajah Mungkur	9,712	0	0	9,712
4	Gayamsari	6,061	0,223	0	6,285
5	Genuk	9,128	17,515	0	26,643
6	Gunung Pati	25,989	33,677	0	59,665
7	Mijen	57,820	0	0	57,820
8	Ngaliyan	26,957	17,521	0	44,477
9	Pedurungan	1,340	20,797	0	22,137
10	West Semarang	1,789	20,866	0	22,655
11	South Semarang	6,171	0	0	6,171
12	Central Semarang	5,360	0	0	5,360
13	East Semarang	5,628	0	0	5,628
14	North Semarang	1,945	9,279	0	11,224
15	Tembalang	0	4,088	36,080	40,168
16	Tugu	0	3,054	26,685	29,739

Total	195,424	127,019	62,765	385,208
Percentage (%)	50,732	32,9742	16,2938	100

Data generated by authors (2019)

Finally, the number of regions that have a low level of risk of *Angin Puting Beliung* in Semarang can be caused by the high level of capacity and the low level of vulnerability. However, it is worth noting that in terms of potential danger to *Angin Puting Beliung*, the majority is medium. This is because a high capacity in an area allows a high level of resilience to disasters. In other words, areas with residences that already understand how to deal with the potential *Angin Puting Beliung* danger and participate in reducing vulnerability in the area from existing threats, can minimize the impact and losses caused by the disaster. As for the high risk of *Angin Puting Beliung* disaster, it can be caused by the low level of disaster capacity and the level of danger which is classified as medium to high, even though the vulnerability is classified as low to medium. This has an effect because at low capacity it can be concluded that the area has not been able to withstand the potential of a cyclone occurrence, or in this case, the population do not understand yet how to deal with and reduce the level of a tornado in Semarang. The complete spatial distribution of risk of *Angin Puting Beliung* in Semarang City can be seen in Figure 8 as follows.

Figure 8. Risk Level of *Angin Puting Beliung* Map

3.2 Discussion

There have been several studies on hazard, vulnerability, capacity and risk analysis in Semarang city and beyond. For instance, I.P (2014) conducted a study of GIS Applications in Determining the Location of Urban Forests as Disaster Mitigation in Bondowoso sub-district. The method used is the overlapping of each parameter through the scoring process. The results of this study are that the characteristics of villages that frequently experienced cyclones, including lowland areas that are below 500 meters above sea level, are flat areas. They have 0-8% slope area of 1045.07 ha or as much as 89, 21%, which their temperatures are between 30°-35°C covering an area of 909.45 ha or as much as 77.63%. Paddy fields covering an area of 853.45 ha or 72.85%, are among the most affected areas.

Then, Handoko et al (2017) studied Semarang Vulnerability Mapping Study on Multi Disasters, based on Remote Sensing and Geographic Information Systems. The method used is the overlapping of each parameter through the scoring process. The results of this study are that 3,320% of the total area of extreme weather has a low vulnerability, equivalent to 1,281,344 Ha. 65,498% of the area (25,278,891 Ha is a medium vulnerability. The high vulnerability area is 31.182%, equal to 12,034,755 Ha.

Another research was conducted by Fachmawati et. al (2017) about the level of public knowledge on the level of *Angin Puting Beliung* disaster preparedness in Sragen Kulon sub-district, Sragen Regency. The method used was a survey. The findings show that the level of disaster knowledge is 38.5% in the medium category, the level of preparedness is 27.8% in the medium category, the disaster warning level is 40.2% in the medium category, and the disaster alert action is 44% in the medium category. This means that the level of public knowledge on the level of disaster preparedness in *Angin Puting Beliung* in Sragen Kulon is medium category, which is not quite good.

We argue that previous studies discussed above are limited to only assessing the danger, vulnerability and capacity but did not include a comprehensive risk assessment. In Bahri's research, Bondowoso has different characteristics from Semarang, but the results of the study show several parameters showing similarities of both areas such as the influence of morphology, land use, and temperature with a difference in one of the parameters namely rainfall not in the study. Then in the condition of each parameter where Bondowoso has more flat morphology with a lot of open land, which is different from Semarang that has a flat

morphology but the open land is limited. These conditions are likely to affect the potential danger of *Angin Puting Beliung* in Semarang.

Likewise, Handoko's study above is also almost identical to this study on the level of disaster vulnerability and the results are quite similar. However, the timeframe is different as the former study was conducted in 2016 while the latter was in 2018 which offers the most updated disaster vulnerability. The variables used by Handoko were also different in the sense that social and physical vulnerability refers to sex and public facilities respectively. In our study, we use the number of buildings for physical variables and vulnerable groups for social variables because they are more general and contextual. The last research by Fachmawati et. al (2017) explained the stages of regional capacity and used survey for data collection. However, their data cannot be juxtaposed with this study. Their research focus was limited to the sub-districts in Sragen Regency while our study examines the entire city of Semarang.

Finally, the differences of this study with previous research are in the method and purpose. The method used is a survey method by determining the amount of accuracy of the modeling that has been done with the field conditions. This approach is more accurate in the field, using a combination of event data from the local BPBD Semarang. In its weighting using AHP, the parameters are most influential to investigate the disaster exposure. In addition, we employ the surface air temperature parameters, aimed at not only to map but also analyze the impact of the risk.

4. Conclusion

Our concluding notes are as follow. Firstly, the potential level of *Angin Puting Beliung* hazards that spread evenly in Semarang is known to almost all potential areas, with a high potential hazard known to have an area of 109,793 Km² or 28,502% with most of it located in Ngaliyan, Mijen, Gunung Pati, Banyumanik, West Semarang, Central Semarang, North Semarang, South Semarang, East Semarang, Tembalang, Pedurungan, Genuk, and Gayamsari. Secondly, High vulnerability is known to be in four sub-districts namely West Semarang, Mijen, Gunung Pati and Tembalang. For the low vulnerability class, six sub-districts were found, namely Tugu, Gajah Mungkur, Candisari, South Semarang, East Semarang, and Gayamsari. While the rest of the vulnerability classes are in six sub-districts including Ngaliyan, Banyumanik, North Semarang, Central Semarang, Genuk, and Pedurungan.

Finally, the results of *Angin Puting Beliung* risk analysis show that some Tugu and Tembalang sub-districts are known to be at high risk because their capacity levels, an area of 62.765 km² or 16.293%. The area of medium risk level is 127,019 km² or 32,974% which include part of Tugu, Gunung Pati, Ngaliyan, West Semarang, North Semarang, Genuk, and Pedurungan sub-districts. The risk of the low class is the widest, reaching 195.424 km² or 50.732% of the area, covering almost the entire city of Semarang. All of these findings indicate the high exposure and vulnerability of Semarang to the *Angin Puting Beliung*.

References

- Badan Pusat Statistik. 2018. *Kota Semarang dalam Angka 2018*. Semarang
- Bahri, P. I. 2014. Aplikasi Sig Dalam Penentuan Lokasi Hutan Kota Sebagai Mitigasi Bencana Angin Puting Beliung Di Kabupaten Bondowoso. *Skripsi*. Fakultas Kehutanan Institut Pertanian Bogor
- Djamaluddin. 2012. Memahami Badai tropis, Angin Kencang, dan puting Beliung. jurnal. Deputi Sains LAPAN. Jakarta
- Faizana et al .2015.Pemetaan Risiko Bencana Tanah Longsor Kota Semarang .Jurnal Geodesi Undip . Fakultas Teknik, Universitas Diponegoro
- Fakhrurrozi & Sari.2016.Tingkat Ketangguhan Bencana Di Kota Semarang Berdasarkan Survei Mastaben .Prosiding Geotek Expo Puslit Geoteknologi LIPI.
- Handoko. 1995. klimatologi dasar, landasan pemahaman fisika atmosfer dan unsur unsur iklim. bogor: pustaka jaya
- Handoko et al. 2017. Kajian Pemetaan Kerentanan Kota Semarang Terhadap Multi Bencana Berbasis Pengindraan Jauh Dan Sistem Informasi Geografis . Jurnal Geodesi Undip . Fakultas Teknik Universitas Diponegoro
- Ilham, W., & Kadir, S. 2009. *Investigasi Dan Model Terpadu Untuk Menduga Dampak Angin Puting Beliung Di Kawasan Hutan Dan Pedesaan Di Provinsi Kalimantan Selatan*. Jurnal Hutan Tropis Borneo. Volume 10 No. 28. Hal 292-304.
- Martono. 2017. *Impacts of Extreme Weather on Sea Surface Temperature in the Western Waters of Sumatera and the South of Java in June 2016*. Forum Geografi, Vol 31 (1) July 2017: 108-117 . Forum Geografi, Vol 31 (1) July 2017: 108-117 .Centre of Atmospheric Science and Technology (LAPAN)
- Nurjani, E., Rahayu, A., & Rachmawati, F. 2013. *Kajian Bencana Angin Ribut Di Indonesia Periode 1990-2011: Upaya Mitigasi Bencana*. Jurnal Geomedia. Volume 11 Nomor 2.
- Nurlambang, T., dkk. 2013. Penanggulangan Bencana Cuaca Ekstrem di Indonesia. Jurnal. Mataram: Prosiding Seminas Riset Kebencanaan.
- Peraturan kepala BNPB No 02 Tahun 2012 tentang Pedoman Umum Pengkajian Risiko Bencana
- Peraturan Kepala Badan Meteorologi, Klimatologi, dan Geofisika No: KEP 009 tahun 2010 tentang Prosedur standar operasional pelaksanaan peringatan dini, pelaporan, dan diseminasi informasi cuaca ekstrem
- Prawiwardoyo, S., 1996. Meteorologi. Bandung: Penerbit ITB

- Putra, Ks. B. P. 2015. Analisis Kerentanan Bangunan Terhadap Bencana Angin Puting Beliung Di Kecamatan Tanon Kabupaten Sragen. *Skripsi*. Fakultas Geografi Universitas Muhammadiyah Surakarta.
- Putuhuru, Ferad. 2015. *Mitigasi Bencana dan Penginderaan Jauh*. Yogyakarta: Graha Ilmu
- Saaty, T.L. (2008). *Decision Making with the Analytic hierarchy process* Katz Graduate School of Business, University of Pittsburgh, USA: *Int. J. Services Sciences*, Vol. 1, No. 1, 2008
- Utomo, Dwiyono Hari. 2016. Meteorologi Klimatologi. Bantul: magnum pustaka utama

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