RISK MAPPING STUDIES OF HYDRO-METEOROLOGICAL HAZARD IN DEPOK MIDDLE CITY

Jachrizal Soemabrata[1], Ahmad Zubair[2], Irene Sondang[1] and Esti Suyanti[1]

[1]School of Strategic and Global, Universitas Indonesia, Indonesia; [2]Center for Urban and Regional Research, Indonesia

ABSTRACT: Rapid population makes rapid activity at limitation space. It will increase the potential for conflict within natural or environmental resources. Urbanization in Indonesia cities results in the tight competition of resources between urban dwellers, especially in satellite city like Depok as the consequences Jakarta's spill over. Depok more experiences with flood and landslide since the rapid population pressure. Instead of doing curative action deal with the disaster, this city should do preventive action by doing risk mapping. This research will guideline to identify the vulnerability and capacity of its city in dealing with hydro-meteorological hazard. It will conduct by mix method approach using GIS technique and statistical analysis to determine the risk mapping. This research will show the spatial variation of risk that (potential) occurred related to hydro-meteorological in Depok City. Through risk mapping studies, this study will examine the balancing of population growth with the environment acceptances at the middle city in Indonesia.

Keywords: Risk Mapping, Hydro-Meteorological Hazard, Vulnerability, Capacity, Middle City

1.   INTRODUCTION

Geographically, Indonesia is located among three tectonic plates of earth, they are Eurasian, Pacific and Indo-Australian plates. Indonesia is also located in the ring of the fire area. This location causes 62 % of 497 cities in Indonesia have a high-risk level of disaster [1]

Since 2011, Indonesia has entered a period of development, called urban millennia, a situation where the number of urban residents is greater than rural areas. This condition can be seen from the population in big cities such as Jakarta which continues to increase every year.

Indonesia's major cities have a strategic role to play in the development of the region as a service, collection, and distribution node, which has a backward relationship with its intermediate and hinterland cities as well as forward relationships with other big cities [2]. Unfortunately, the growth rate and growth of middle cities are relatively uneven and tend to be uncontrolled then causing many problems.

One of the middle cities in Indonesia in Depok. Depok's development tends not to look at the characteristics of the city itself, consequently the physical burden that needs to be borne by the city even increases. If this situation still exists, it will lead to large of potential disasters and run down the growth process that will make the slow pace of urban development.

Responding to the importance of disaster and urban issues in Indonesia's development, it is necessary that every city in Indonesia has a tool that can measure disaster risks, one of them through making maps. The map can give several disaster information by linking 3 aspects. These aspects are the potential disasters occurring in the city, the vulnerability of cities and the roles and capacities of both communities, NGO, and governments.

2.   LITERATURE REVIEW

Disaster risk assessment is an approach to show potential negative impacts that may arise from a potential disaster. Disaster risk assessment in the previous research was conducted on a provincial scale using GIS by the government. The disaster threats experienced by middle cities in Indonesia are hydro-meteorological disasters. It is hydrometeorological (i.e., floods, landslides) and climatological disasters (i.e., droughts and heat waves), rather than the geophysical disasters (i. e., earthquakes and volcanic eruptions), that has been trending upwards in recent decades. This rising trend of climate-related hazards suggests a possible connection between these hazards and in turn disasters on the one side and climate change on the other [3].

Hydrometeorological disasters greatly affect the resilience of communities within the middle city. The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. Figure 1 shows many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include poor design and construction of buildings, inadequate protection of assets, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for wise environmental management. [4]
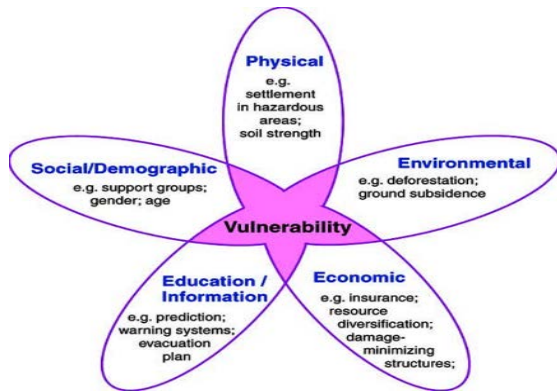
Fig. 1   5 Aspects to Assess Vulnerability

Souza [5], stated that potential damage and risk maps are automatically built up within the GIS (any other geoprocessing software may be used), then any change in environmental characteristics might be easily updated, allowing that all of the thematic maps involving the Risk Assessment be rapidly modified too.

Hydrometeorological disaster risk reduction is not only done with the construction and management of facilities and infrastructures, in accordance with National Law Number 26, 2007 about Spatial Planning, the Republic of Indonesia located in disaster-prone areas requires spatial planning based on disaster mitigation as an effort to improve the safety and comfort of life and preserve the environment [6].

3. METHODOLOGY

There are 3 components of indicators for calculating the disaster risk of a region. Those indicators are a hazard, vulnerability, and capacity. At this stage, the study will be conducted to explore the risk assessment methods that used in government guidelines through the Head of National Board for Disaster Management Regulation No 2/2011 as well as recommendations from the United Nation International Strategy for Disaster Reduction (UNISDR).

$$R = \frac{H \times V}{C} \qquad (1)$$

R   = Risk
H   = Hazard
V   = Vulnerability
C   = Capacity

Based on National Board for Disaster Management [8], equation (1) is a risk assessment method linking potential hazard and vulnerability in Depok City, then divide by its capacity. The review will be followed by a case study conducted in Depok City. It is hoped that by studying the application in the case study, some learning outcomes will be useful for the improvement of the formulation.

3.1 Hazard Assessment

Hydro-Meteorological hazards are caused by extreme meteorological and climate events, such as floods, droughts, hurricanes, tornadoes, or landslides [7]. The focus of research is floods and landslides. Flood disaster can be calculated and classified into

Table 1   Flood Classification and Score

Depth (m)	Class	Value	Weight (%)	Score
<0.76	Low	1		0.3
0.76-1.5	Mid	2	100	0.6
>1.5	High	3		1

Source: National Board for Disaster Management

Landslides can be calculated and classified into:

Table 2   Landslide Classification and Score

Threat Zone	Class	Value	Weight (%)	Score
Low Ground Movement	Low	1		0.3
Medium Ground Movement	Mid	2	100	0.6
High Ground Movement	High	3		1

Source: National Board for Disaster Management

3.2 Vulnerability Assessment

The vulnerabilities that can be identified in this study are an economic and social vulnerability. Indicators used in vulnerability analysis are primarily exposure and loss information. The sources of information used for analysis can come from Central Agency on Statistics data and basic map information.

The economic vulnerability can be calculated by the following equation:

Table 3   Economic Vulnerability Classification

Parameter	Weight (%)	Class (Million)			Score
		Low	Mid	High	
PL	60	<50	50-200	>200	Class/ Max Score
GDRP	40	<100	100-300	>300	

Source: National Board for Disaster Management

$$EV = (0.6 \times PL\ score) + (0.4 \times GDRP\ Score) \quad (2)$$

EV   = Economic Vulnerability
PL   = Productive Land
GDRP   = Gross Domestic Regional Product

The social vulnerability can be calculated by the following equation [8]:

Table 4   Social Vulnerability Classification

Para meter	Weight (%)	Class			Score
		Low	Mid	High	
PD	60	<500	500-1000	>1000	Class/ Max Score
SR PR DR AR	40	< 20%	20-40%	> 40%	

Source: National Board for Disaster Management

$$SV = \left(0.6 \times \frac{log\left(\frac{PD}{0.01}\right)}{log\left(\frac{100}{0.01}\right)}\right) + (0.1 \times SR) + (0.1 \times PR) + (0.1 \times DR) + (0.1 \times AR) \quad (3)$$

SV   = Social Vulnerability
PD   = Population Density
SR   = Sex Ratio
PR   = Poverty Ratio
DR   = Dissabled Ratio
AR   = Age Ratio

3.3 Capacity Assessment

The capacity index is calculated based on indicators in the Hyogo Framework for Actions (HFA). The HFA agreed by more than 160 countries in the world consists of 5 Priority DRR programs. Achieving these disaster risk reduction priorities are measured by 22 indicators of achievement [8].

Table 5 Capacity Classification and Score

Para meter	Weight (%)	Class			Score
		Low	Mid	High	
RADMI EWS DE BRFR DODP	100	<0.3	0.3-0.6	>0.6	Class/ Max Score

Source: National Board for Disaster Management

Capacity Index = (1 x Capacity Score)   (4)

RADMI   = Rules and Disaster Management Institution
EWS   = Early Warning System
DE   = Disaster Education
BRFR   = Basic Risk Factor Reduction
DOP   = Development of Disaster Preparedness

4. RESULT AND DISCUSSION

4.1 Hazard

4.1.1 Flood

Floods are overflow water that exceeds the capacity of rivers in their canals that are usually preceded by high rainfall or high flow water from upstream areas. Due to its vast territory, flood in different areas manifests themselves in different types and with various characteristics [9]. Flood and inundation problems are caused by high rainfall, modified or disturbed river morphological conditions, poor drainage systems, and other external factors such as high river sedimentation and landslides.

Fig. 2   Flood Area in Depok City in 2015

Some district is potentially affected by the flood. The flooded districts spread throughout Depok City and are dominated in the east of the city. Some areas prone to flooding tend to be passed by large streams such as Ciliwung and Pesangerahan River. The average depth of flood in Depok city is about 50-100 cm, or even reach 200 cm in certain area.

Floods are indirectly related to so massive land use changes. Land use/land cover will be given for making land use monitoring system [10]. It is understood that floods occur because of the unplanned rapid urbanization, change in land use and poor watershed management mainly in floodplains become important issues for consideration as the flood causes [11].

Flood also affects the availability of water. Study of the run-off transformation on the land surface is especially important in built-over areas, where basic natural landscapes are modified [12]. In addition to the area being a reservoir of water, many ponds and fish ponds are both consumption and aquaculture that

can become a water reservoir when heavy rains so that the overflow of river water can still be handled.
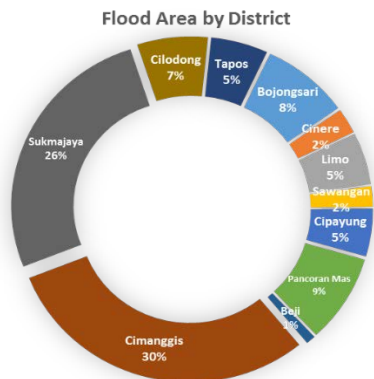

Fig. 3   Flood Areas Percentage by District in 2015

Based on Soemabrata [13], figure 3 shows that Depok City has a flood-prone area of 126.4 Hectares, Sukmajaya District became the most potentially affected by floods with an estimated total area of 32.8 Hectares. In addition, flood-prone areas in Depok City tend to be located at an altitude of fewer than 100 meters which includes a declivous area.

4.1.2 Landslide

Landslide in Depok City occurs due to several factors both from the physical condition of the region and the natural factors of Depok and human activity in it. According to Matheus [14], measuring the level of landslide hazard can be determined based on seven natural physical parameters consisting of the slope, soil, rocks making up the slope, rainfall, land use, seismicity, and fault.
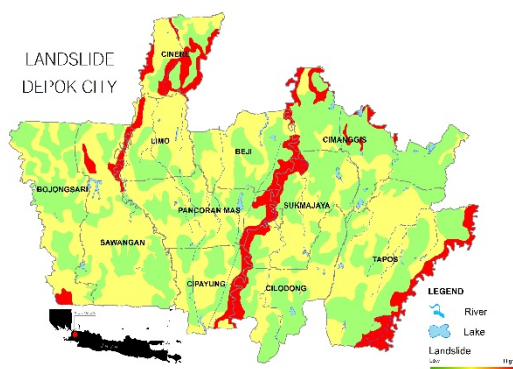

Fig. 4   Landslide Area in Depok City in 2015

Factors caused by humans can be in the form of piles of garbage and the accumulation of material caused by the expansion of settlements so that piling up the soil around the valley leads to overloaded land, and there are farms on the slopes. Potentially landslide-prone areas are located along large rivers that have a fairly steep slope. Geological and geomorphological conditions (e.g., material type, strength and structure, and slope angle) predispose slopes to failure; knowledge of these conditions can help to predict the location, types, and volumes of potential failures [15].

Figure 4 shows the landslide-prone area in Depok City is on the slope between 8-15% which means that the slope condition is quite steep and has a steep hill or valley. This region is often found along a large river flow that has a river width of more than 10 m. The steeper the slope, the higher the landslide potential, but this can't be separated from the type of rock and soil type in the area.
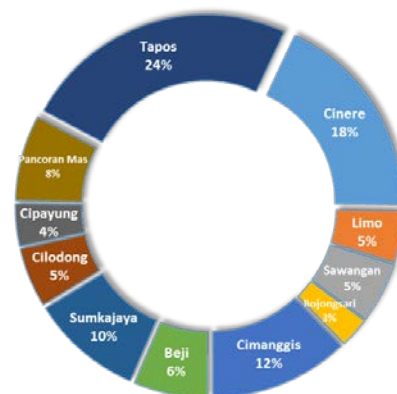

Fig. 5   Landslide Areas Percentage by District in 2015

Based on Soemabrata [13], figure 5 shows areas prone to landslides in the city of Depok reach 1807 Hectares in the area. The most vulnerable areas of landslides are Tapos and Cinere Districts with a total of 7 vulnerable villages. This region has a fairly steep slope along the stream.

4.2 Vulnerability

The vulnerability can simply be defined as exposure x sensitivity [16]. The vulnerability is considered as a result of the interactions between physical (territorial) characteristics and the susceptibility and the capacities of the socioeconomic system to adapt and cope with a specific hazard, expressed as a nondimensional index ranging between 0 and 1 [17]. The vulnerability of Depok City can be divided into economic, social, physical and environmental vulnerabilities.

4.2.1 Economic Vulnerability

Indicators used to measure the economic vulnerability of Depok City is the area of productive land and GDP of the city. The area of productive land can be obtained from land use maps and district/city or sub-district books in figures and converted into

rupiah, whereas GRDP can be obtained from the sector or district reports in figures. The weight of the index of economic vulnerability is almost the same for all types of threats, except for building fire and residential and settlement fires.
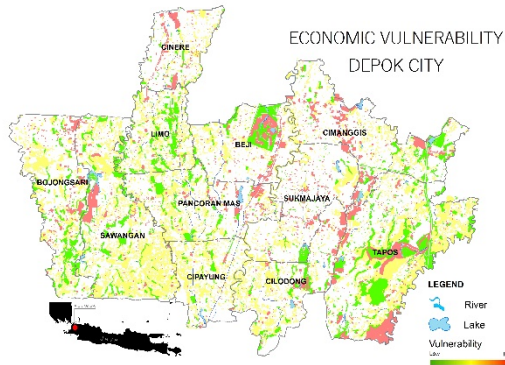

Fig. 6   Economic Vulnerability Area in Depok City in 2015

Figure 6 shows the area with the highest level of economic vulnerability is located in the suburbs with a total area of 629 Hectares. Based on the data and field observations that have been done, there are 8 most vulnerable districts. One of them is located in the vital areas of the city.Most of them have productive land (e.g. offices, services and trading area, plantations) that play an important role in economic activity. The rise of land use change has also become one of the causes of economic vulnerability index which is still continuously increasing every year.
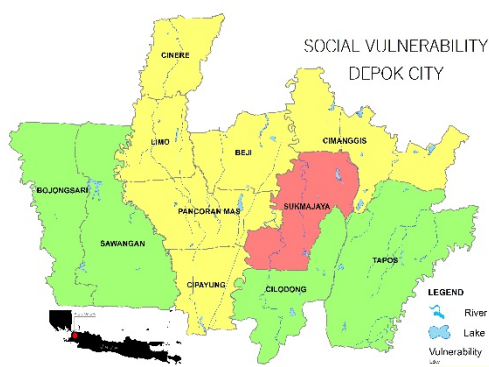
4.2.2 Social Vulnerability

Fig. 7   Social Vulnerability Area in Depok City in 2015

Indicators used for social vulnerability are population density, sex ratio, poverty ratio, disabled ratio and age group ratio. Figure 7 illustrates the distribution of areas with levels of social vulnerability. Where each indicator of each district has different vulnerability lift. Areas with high social vulnerability

are only in Sukmajaya District. This is consistent with the high population density in the region. In addition to population density, the more disability and the number of vulnerable age groups, the more vulnerable the District to Hydro-Meteorological hazard.

Areas with low social vulnerability are located in some districts located in the suburbs. In addition, in the region in some indicators also shows are in low grade. Broadly speaking, it can be said that the more towards the center of the city, the level of social vulnerability is increasing. Vice versa, the more towards the suburbs, the lower the social vulnerability.

4.3 Capacity

The policies and regulations on the disaster in Depok City are still overlapping. This is due to the absence of agencies that focus on disaster management affairs. Unlike other cities such as Jakarta that already have Regional Board for Disaster Management (BPBD DKI Jakarta), BPBD Depok needs to be completed because the level of disaster threat is increasing every year. For now, disaster-related policies are downgraded into several plans and programs can be identified through urban planning regulation (RDTR Depok City in City Regulation No.1 Year 2015). The plans and programs are as follows:

Table 6 Flood and Landslide Management Program

Item	Program
Flooded Area Plan	Normalization of drainage channels
	Building new channels to the river
	Building embankments
Landslide Area Plan	Protecting and building of river/lake walls
	Normalization of riverbank and lake with mud dredging and develop jogging track
	Building an evacuation road
	Reforestation by planting landslide prevention plants along riverbank
	Limit the utilization of space around riverbank

Source: Urban Planning of Depok City

Several programs can also be identified through a series of Focus Group Discussions (FGD) with the Local Government of Depok City and field findings.

5. CONCLUSION

Depok City based on the identification of potential hazard threat variables and have historical data related to Hydro-Meteorological hazard that is floods and landslides. Meanwhile, the susceptibility variable successfully identifies two aspects, those are an economic and social aspect. Two other aspects (environmental and physical vulnerability) have not been identified due to data limitation. While the capacity variables successfully identified that there has been disaster management programs even though the activities that are preventive are still small. One of them is due to the lack of focus on disaster management because it does not have BPBD yet. The future research should be more focus on the measuring the risk index. Governments need to work with communities to build capacity and reduce vulnerability levels with more planned mitigation programs. In addition, the establishment of disaster management in the city-level is urgently needed.

6. ACKNOWLEDGEMENTS

7. REFERENCES

[1] State Ministry for Development Planning,"Disaster Index Reduction in Indonesia", Jakarta: National Board for Disaster Management, 2014.

[2] Soemabrata. J, "Hydro-Meteorological Hazard Risk Assessment in Slum Area Depok City through Health Aspects, Community Adaptation Capacity, and Availability of Basic Infrastructure", Depok: Universitas Indonesia, 2016, ch 1.

[3] Thomas V, "Confronting Climate-Related Disasters in Asia and Pacific", Jahrbuch für Wirtschaftswissenschaften Review of Economics, Vol. 2, 2014, pp. 121-135.

[4] United Nations International Strategy for Disaster Reduction (UNISDR), "Global Platform for Disaster Risk Reduction", 2nd Session, Geneva, Switzerland, June 2009.

[5] Souza, C.R. de G, "Flood Risk Assessment in Coastal Drainage Basins through Multivariate Analysis within a GIS-Based Model", J. of Coastal Research, Vol.1, 2009, pp. 900-904.

[6] M.R. Amri *et al,* "Resiko Bencana Indonesia". Jakarta: Indonesian National Board for Disaster Management, 2016, ch. 2.

[7] Huan Wu *et al*, "Hydrometeorological Hazards: Monitoring, Forecasting, Risk Assessment, and Socioeconomic Responses", J. of Advances in Meteorology, Vol. 2016, Aug. 2016, pp. 1-3.

[8] M.R. Amri *et al,* "Resiko Bencana Indonesia", Jakarta: National Board for Disaster Management Regulation, 2016 ch 3.

[9] Zhong Guihui *et al*, "Urban Flood Mapping for Jiaxing City Based on Hydrodynamic Modeling and GIS Analysis", J. of Coastal Research, Vol. 1, 2014, pp. 168-175.

[10] K. Djaja *et al,* "The Integration of Geography Information System (GIS) and Global Navigation Satelite System-Real time Kinematic (GNSS-RTK) For Land Use Monitoring", International Journal of GEOMATE, Vol.13, Aug 2017, pp.31-34.

[11] N.F Ibrahim *et al*, "Identification of Vulnerable Areas to Floods in Kelantan River Sub-Basons By Using Flood Vulnerability Index", International Journal of GEOMATE, Vol. 12, Jan 2017, pp. 107-114.

[12] A.V. Bobylev, A.V. Malaev, N.S. Rasskazova, "The Geoecological Modelling of Small Water Reservoirs and River Catchment Areas as a Procedure in Urban Development", Procedia Engineering, Vol. 150, 2016, pp. 2067-2072.

[13] Soemabrata. J, "Hydro-Meteorological Hazard Risk Assessment in Slum Area Depok City through Health Aspects, Community Adaptation Capacity, and Availability of Basic Infrastructure", Depok: Universitas Indonesia, 2016, ch 4.

[14] S. Matheus, H. Lilik, H. Gunawan "Landslide Hazard and Risk Assessment for Ambon City using Landslide Inventory and GIS", J. Of Physics: Conference Series 739, 2016, pp. 1-11.

[15] Samuel T. McColl, "Landslide Causes and Triggers", Landslide Hazards, Risk and Disasters. Amsterdam: Elsevier, 2015, pp. 17-42.

[16] R.R Putra, J. Kiyono, A. Furukawa, "Vulnerability Assessment of Non-Engineered Houses Based on Damage Data of The 2009 Padang Earthquake in Padang City, Indonesia", Int. J. of GEOMATE, Vol. 7, Dec. 2014, pp. 1076-1083.

[17] Giupponi Carlo *et al*, "Integrated Risk Asssessment of Water-Related Disasters", Hydro-Meteorological Hazards, Risks, and Disasters. Amsterdam: Elsevier, 2015, pp. 163-200.