Health risk assessment and flood hazards in the context of strategic environmental assessment (sea) in west java – a spatial analysis

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Abstract. One of the main contents of strategic environmental assessment (SEA) is the assessment of environmental and health risks. So far, the risk assessment has not been a big part of the SEA and spatial planning in Indonesia. Further, there is no agreed methods how to assess health risk and flood hazards in the context the SEA. Therefore, this study aims to develop a methodology of health risk assessment and flood hazard in the context of SEA by using meta-analysis, determining of weights indicators, and spatial analysis. The development of this methodology was then applied in West Java Province. The development of the methodology based on Regulation of the National Disaster Management Agency Head Number 2 of 2012, SNI 8197-2015, document review study, and analytical hierarchy process. Spatial analysis using ArcGIS software. Based on the result. The analysis was obtained 3 risk classes and from the total area of West Java Province was found that 57.24% (21,228,362,159 ha), 41.75% (15,484,436,486 ha), and 1% (372,685,808 ha) has a low, medium, and high environmental health risks assessment.

1. Introduction

Rapid population growth and increased exploitation of natural resources reduce environmental quality [1]. Environmental degradation is one of the factors causing a significant burden of death and disease - globally and particularly in developing countries [2]. Studies conducted from OECD countries have concluded that 2.1% -5.0% of the total disease burden is due to the environment [3]. To overcome the environmental quality problems and their consequent health issues, sustainability perspective needs to be integrated into regional development plans and activities.

One of the efforts to ensure that sustainable development has been mainstreamed in regional development plans, the Government of Indonesia mandates the preparation of a Strategic Environmental Assessment (SEA) as an integrated part of development policies, plans and/or programs (PPP). Government Regulation Number 46 of 2016 concerning Procedures for Implementing Strategic Environmental Assessment (SEA) indicates that environmental and health risk assessment is one of the contents in SEA. Environmental and health risk assessment can serve as a decision support tool in sustainable development and planning [4]. The scope of environmental health risk assessment can include the health impacts of chemical pollutants and contaminants in air, water, soil and food, pathogenic microbiological contaminants in food and water, sources of radiation, electromagnetic fields, and climate change [5]. Conventionally, environmental and health risks are calculated by risk analysis which is used as an assessment of environmental impacts on health [6]. However, most environmental and health risks in the context of sustainable planning and development are systemic; where the risks are complex and embedded in the broader environmental, social-economic, and political systems. Systemic risk is challenging to identify from the cause-and-effect relationship between certain hazards and effects and is difficult to quantify due to different interpretations of the same risk phenomenon. Therefore, direct hazard-consequence analysis is not sufficient to assess systemic risks with growing and non-linear hazards in the context of sustainable development and planning, particularly in SEA or SEA [7-9].

At this moment, risk assessment methods in Indonesian SEA are scarce. This study aims to develop a novel method in assessing systemic risks in the context of SEA. In this study, the risk assessment carried out was to analyze the environmental health risks resulting from one of the most frequent risks affecting life and damage to vulnerable areas: flooding.

In the last few decades, the increasing frequency of disasters, especially floods, has threatened human life and infrastructure causing greater economic losses [10]. Several studies have been conducted indicating that climate change and land use are the main drivers of the increasing number of flood events [11-13]. The IPCC report [14] indicates that a large number of areas are likely to experience extreme rainfall and flood events in the future. Natural water bodies, such as lakes, wetlands, and waterways that can hold large amounts of flood water have been largely reduced due to changes in land use, increasing the incidence of flooding. The increasing frequency of floods can threaten human life and infrastructure [15]. In addition, the most widespread and significant impacts of flooding are the risks they pose to health, ranging from death and injury from trauma and drowning to waterborne and vector-borne diseases, and mental health problems (acute and long-term) [16]. These impacts occur directly through contact with floodwaters or indirectly from damage to infrastructure, ecosystems, food, and water supplies or social support systems that can occur immediately or occur days, weeks or months after the flood recedes [16 -18]. Most of the evidence on the link between flooding and health lies in its immediate impact [16-20].

Understanding the above impacts, the Government of Indonesia had formulated the Climate Change Adaptation National Action Plan [21], addressing the issue of extreme weather events, such as floods, in relation to various development sectors, including health. The action plans are directed on updating the risk assessment and climate change adaptation in the health sector at the district/municipality levels, observation and control of disease agents, disease intermediaries, environmental quality, and infection in humans, especially in vulnerable groups, such as women, children, elderly and low-income communities. This is further elaborated into Local Action Plan (RAD-API) which also mandated the localities to conduct a comprehensive health risk assessment in relation with various climate change problems, including floods. However, to the best our knowledge, there is no agreed methods how to assess risk assessment related to flood hazards is used into the development policies, plans and programs in the SEA.

In this study, a novel approach how to perform an environmental health risk assessment of flood risk was carried out using meta-analysis, multiple criteria decision analysis for determining weights of selected indicators, and spatial analysis. This will guide areas-at-risks and the information feeds into policies, plans, and/or programs in the Strategic Environmental Assessment (SEA).

2. The Development of Method

This paper presents a new methodology for an environmental risk assessment related to flood hazards that can be used into the development policies, plans and programs in the SEA, especially in Indonesia. As presented in **Figure 1**, the proposed methodology integrates qualitative and quantitative approaches and it consists of three main steps: meta-analysis to define indicators used for map processing, indicator weights used for scoring, and development of a series of thematic maps and environmental health risk map.

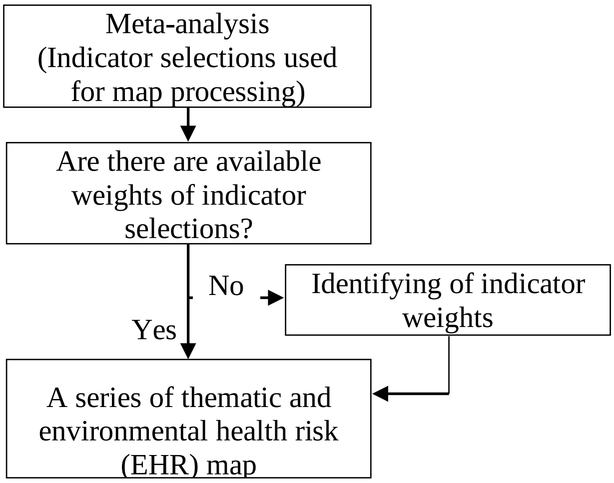

Figure 1 Proposed methodology of environmental health risk assessment

The first step, which is meta-analysis, was performed to identify available methods and approaches for environmental health and risk assessment in the context of SEA. This meta-analysis includes identification and description of primary studies, considerations of quality and fit, and generating labels and categories [22]. Since the EHR was developed specifically to suit environmental health perspectives of Indonesia, the meta-analysis outlined this issue through understanding how the concept of risk, risk management, and risk governance can be best articulated and integrated into Indonesia's SEA. Locating of primary studies published between 2009 and 2019 in English through Google Scholar, omitting unpublished studies or grey literature and doing an inventory of EHRA methods and review of paper related to SEA were undertaken in this study. Through this, selected indicators, were then defined and related data and information were collected to be used for the next steps [23].

As illustrated in **Figure 1**, the second step discusses indicator weights used to indicate the importance of an indicator. The larger the weight assigned to the selected indicators, the more that indicator will influence the outcome of the environmental health risk assessment. The main reference of indicator weights is obtained based on literature review on existing policies, guidelines, and regulations. If they are not available, the indicator weights can be established by applying two broad categories, which are statistical-based methods (objective) and participatory-based methods (subjective). In this study, analytical hierarchy process (AHP) was selected to be used since it is a mature and easy concept to gain experts judgement for assigning weights to the indicators [24]. The overview, advantages and disadvantages, and detailed procedure of the AHP can be found in [25]. In the final step, in general, a spatial analysis was conducted with ArcGIS®. The development of Geographic Information Systems (GIS) has significantly improved the spatial representation and analysis of all types of information and data. Geographical data (topology, etc.) and factual data can be combined into maps using spatial models embedded in ArcGIS®. In addition, GIS software has become easier to obtain and use [26].

The ArcGIS® analysis aims to determine areas-at-risk related to flooding hazard. According to Regulation of the National Disaster Management Agency Head Number 2 of 2012, risk is a function of hazard, vulnerability, and adaptive capacity. Eq. (1).

$$Risk\ (R) = Hazard\ (H)\ x\ \frac{Vulnerability\ (V)}{Adaptive\ Capacity\ (C)} \quad (1)$$

A series of maps were then developed (**Figure 2**). Environmental health risk map (EHR) was generated from the overlays of flood risk map (FR), environmental health vulnerability map (EHV), and environmental health capacity map (EHC). Meanwhile, flood risk map (FR), which was generated from the overlays of flood hazard map (FH), flood vulnerability map (FV), flood mitigation capacity map (FC)

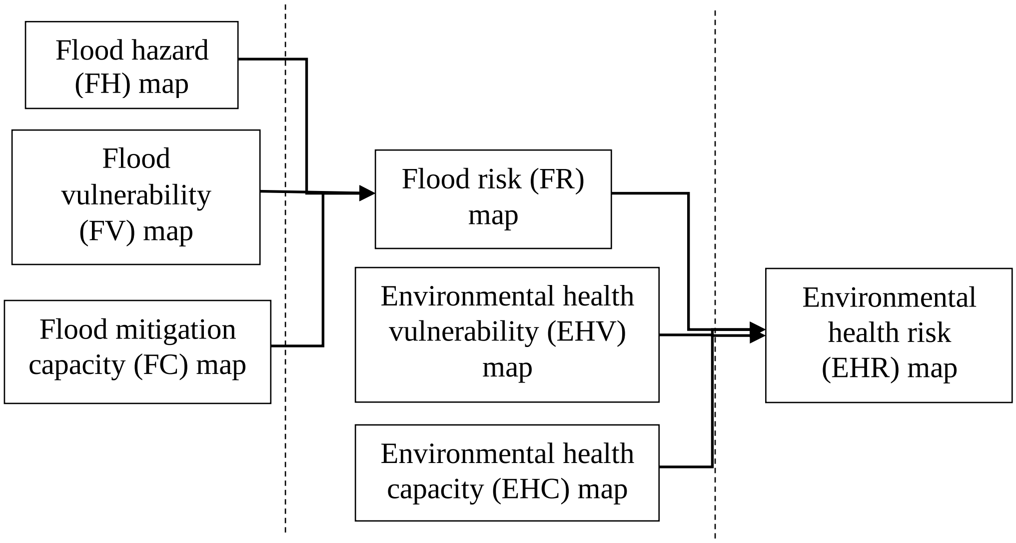

Figure 2 A series of produced map

a. Flood Hazard Map (FH)

The FH map is the result of overlaying indicators of humidity, land cover, and rainfall in ArcGIS®. The FH map serves to identify areas where floods are potential to occur based on the abovementioned indicators [27]. Based on the results of the overlay of the humidity, land cover, and rainfall indicator, three classes of flood risk were obtained: low, medium, and high.

b. Flood vulnerability map (FV)

The FV map was built upon the four components of vulnerability: social, physical, economic, and environmental components [28]. The social component is the result of an analysis of population density and vulnerable groups. Vulnerable groups are groups of people who have limitations in enjoying a decent life, which consists of elderly, children, and people with disabilities, gender ratio, and poverty ratio. The physical component is the result of an analysis of housing, public facilities, and critical facilities. The critical facilities analysis is based on land use of critical facilities which includes health facilities, airports, stations, terminals, and military areas. The economic component is the result of the analysis of gross regional domestic products and productive land. Meanwhile, the environmental component is the result of an analysis of protected forest, natural forest, mangrove forest/mangrove forest, shrubs, and swamps. The assessment of the social component aims to estimate the potential of the population exposed by flood hazard [29]. Meanwhile, the assessment of physical, economic, and environmental component was intended to describe how much loss will be resulted if a flood disaster occurs [29-30].

c. Flood mitigation capacity (FC) map

The FC map is made based on a document review study. The document review study used to determine the indicator of flood mitigation capacity was carried out by reviewing several papers related to flood risk, spatial analysis, and regulations related to disaster capacity. From the document review study, the indicator of flood mitigation capacity indicators was disaster socialization, disaster prediction efforts, and emergency response posts. Since there is no available reference for indicator weights, hence, all the indicators were analyzed using AHP to determine the weight value.

Table 1 Scoring of flood mitigation capacity

Indicator	Weight value (%)	Classes of Capacity		
		Low (1)	Medium (2)	High (3)
Disaster socialization	32	Not present	Weak	Strong
Disaster prediction efforts	49	Not present	Weak	Strong
Emergency response posts	19	Not present	Weak	Strong

d. Flood risk map (FR)

The FR mapping was carried out based on the results of the flood hazard index, flood vulnerability and flood mitigation capacity (Eq. (1)). Risks were classified into 3 (three) classes: low, medium, and high.

Table 2 Risk Index

Interval value	Index	Class
<1	1	Low
1 - 3	2	Middle
>3	3	High

e. Environmental health vulnerability map (EHV)

The components of EHV used in this study are clean water and sanitation indicators. Clean water and good sanitation are very important elements to support human health [31]. Unfortunately, universal access to clean water and sanitation needs has not been fully achieved. Kazi and Rahman [32] stated that the lack of proper sanitation facilities and high groundwater levels in flood-prone areas are among the main factors contributing to health and environmental degradation. Vulnerability in water supply and sanitation conditions, especially during floods, illustrates the vulnerability of health to waterborne diseases during flooding [33]. Poor sanitation and unsafe drinking water contribute to 88% of child deaths due to diarrhea worldwide [34]. All the indicators were analyzed using AHP to determine the weight value. Based on that, the indicator of EHV for the scoring of environmental health vulnerability map was showed in **Table 3**. There are three classes of the vulnerability class: low, medium, and high. The table explains that if >80% of the population has access to proper water sources/sanitation, then the area is included in the low vulnerable-class, whereas if only 50% - 80% of the population has access to proper water sources/sanitation, then the area is included in the middle vulnerable-class. Meanwhile, if only <50% of the population has access to proper water sources/sanitation, then the area is included in the highest vulnerable-class or the most vulnerable.

Table 3 Scoring of environmental health vulnerability map

Indicator	Weight value (%)	Vulnerability Classes		
		Low (1)	Medium (2)	High (3)
Access of water sources	62.9	>80%	50 – 80%	<50%
Access of sanitation	37.1	>80%	50 – 80%	<50%

f. Environmental health capacity map (EHC)

The EHC map was built upon a document review to determine the capacity assessment indicators, then formulating weights and assessments of each of these indicators. The indicators of health capacity used are access to health facilities/services, availability of health workers, health education, and preparedness for emergency response [35]. Each health capacity standard identifies priority resource elements that are relevant to both routine public health activities and essential public health services. As the result of that, government must be prepared to coordinate, cooperate, and collaborate with cross-sector partners in this case health workers to preparedness for emergency response. For this reason, two environmental health capacity classes are obtained to assess the extent to which the capacity of government has implemented to overcome the environmental health. For the assessment of the two classes of environmental health capacity can be seen in **Table 4**.

Table 4 Scoring of environmental health capacity map

Indicator	Weight value (%)	Classes		
		Low (1)	Medium (2)	High (3)
Health facilities/services	30.2	Not present	-	Strong
Availability of health workers	25.6	Not present	-	Strong
Health education	16.8	Not present	-	Strong
Preparedness or emergency response	27.3	Not present	-	Strong

g. Environmental health risk map (EHR)

The EHR map was built upon the overlays of FR map, EHV map, and EHC map. The method used in the environmental health risk assessment for the overlays refers to Regulation of National Disaster Mitigation Agency Head Number 2 of 2012. The EHR purpose to help priorities environmental health and to target effort and resources where they are most needed and likely to be most effective.

3. Study Area

West Java Province, Indonesia, which consists of 27 districts and cities, is used as a study area in this research. With a population of 49,316,710 the province has the highest population in Indonesia [36]. It has natural conditions with a complex geological structure with mountainous areas in the central and southern parts and lowlands in the northern region. As many as 22.1% of the area in this province is forest area. Rainfall ranges from 2000-4000 mm/year with high levels of rain intensity [37].

With its geological, volcanic, climatic, and environmental condition, West Java is one of the most disaster-prone areas in Indonesia. Historical data on the occurrence of disasters shows that floods are the most frequent (32.83%) of total disasters in West Java. Floods are also forecasted to be the number one cause of future potential disasters in West Java [29]. The northern and central parts of West Java have been identified as the most flood-prone region, which are vulnerable to future disasters.

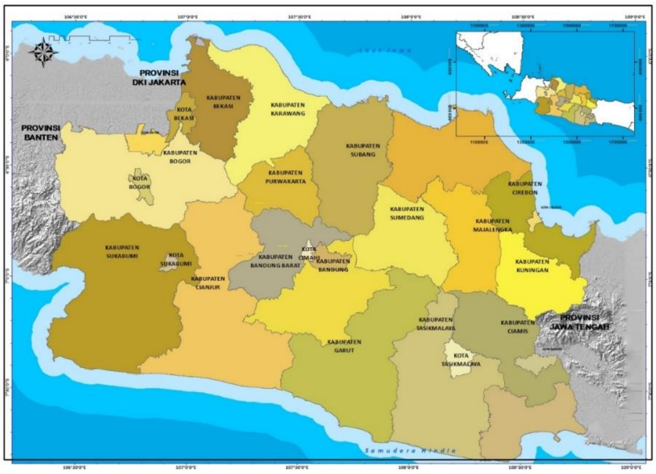

Figure 3 West Java Province (Regional Development Planning Agency of West Java, 2019)

4. Results and Discussion

4.1 Flood Risks (FR) in West Java Province

The FR map is processed through an overlay of 3 (three) maps: flood hazard (FH) map, flood vulnerability (FV) map and flood mitigation capacity (FC) map. **Figure 4** shows the areas-at-risk in relation to flooding in West Java Province.

Figure 4 Flood Risk Map of West Java Province

From the total area of West Java Province, 56.57% (20,978,912,805 ha), 33.85% (12,552,676,083 ha), and 9.58% (3,553,895,565 ha) has a low, medium, and high flood risks, respectively. Sukabumi Regency has the largest high-risk areas (569,985,789 ha or 1.54% of West Java Province).

The flood risk map is the basis used for spatial planning to carry out local hazard assessments or emergency planning and planning of technical protective measures. In addition, these maps are important because they can build awareness and communication about the local hazard situation and the extent of legally defined floodplains [38-39].

4.2 Environmental Health Vulnerability (EHV) in West Java Province

EHV is obtained from scoring the indicators of access of water sources and access of sanitation in West Java Province. **Figure 5** shows the EHP map.

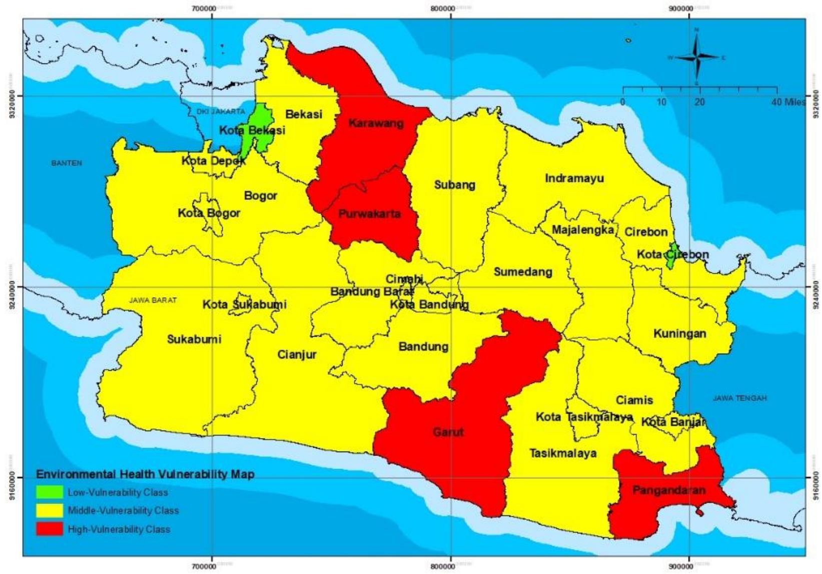

Figure 5 Environmental Health Vulnerability Map of West Java Province

The map shows that in environmental health vulnerability classes, there are 3 vulnerability classes. As can be seen that Cirebon City and Bekasi City belong to the low-vulnerability class, while Garut, Karawang, Pangandaran, and Purwakarta belong to the high-vulnerability class. Meanwhile, 21 other districts/cities are included in areas that are in the middle-vulnerability class.

It is well known that the lack of proper sanitation facilities and high groundwater levels in flood prone areas are one of the main factors contributing to health and environmental degradation [40]. Vulnerability in water supply and sanitation conditions especially during floods illustrates the vulnerability to health to waterborne diseases during floods [33].

4.3 Environmental Health Capacity (EHC) in West Java Province

The map of environmental health capacity is obtained from document review based on the government's ability to provide access to health facilities/services, health workers, health education, and emergency preparedness or response. A map of environmental health capacity can be seen in Figure 6 shows environmental health capacity map of West Java Province.

Figure 6 Environmental Health Capacity Map of West Java Province

The results of all classes show that the class is high-class because all adaptive capacities are implemented and provided by the government. Adaptive capacity can be seen as a function of the ability to access various kinds of resources. That is, individuals who have more access to resources have a higher adaptive capacity than those who have little or no access [41].

4.4 Environmental Health Risk (EHR) in West Java Province

Figure 7 Environmental Health Risk Map of West Java Province

Based on the results of the overlay and calculations, the environmental health risk shown that from the total area of West Java Province, 57.24% (21,228,362,159 ha), 41.75% (15,484,436,486 ha), and 1% (372,685,808 ha) has a low, medium, and high environmental health risks, respectively. Pangadaran Regency has the largest high-risk areas (148,487,001 ha or 0.40% of West Java Province).

Environmental health mapping is an integral part of national or regional health planning and protection policies. However, until now, environmental health maps not used much in various countries. Due, some countries still use mapping of the distribution and magnitude of environmental hazards with the capacity to affect health regardless of population and land use or based solely on environmental information. When examined in more depth, environmental health mapping can focus on the environment and support an essential precautionary approach to policies and interventions that will be able to provide benefits such as showing potential risks to health before they occur [42]. Meanwhile, according to Stieb, et al. [43], one of the most influential uses of environmental health mapping is to inform the public and as a basis for increasing public participation in environmental health protection. In Ghana, a risk mapping document is important to increase the focus of public health emergencies in determining risk-based prevention, preparedness and mitigation, response, and recovery activities [44]. The proposed "Guidelines Based on Environmental Risk Mapping" provide rapid regional environmental risk assessment [45].

5. Conclusion

The environmental health risk mapping based on GIS and multi-criteria analysis is valuable tool for estimating areas prone to environmental health risk, help planners and decision makers to have a reference and focus on specific areas in order to perform an assessment of environmental health risk. Nevertheless, users should be aware of both the strengths and weaknesses of this approach. A new approach in this research paper is the assignment of develop the methods of the environmental health risk that characterize each category from flood hazard using the ArcGIS program. Other than that, using of AHP as the weighting criterion method for the development of the mapping presents several advantages as well.

The results of the study reveal that there were 3 risk classes and from the total area of West Java Province was found that 57.24% (21,228,362,159 ha), 41.75% (15,484,436,486 ha), and 1%

(372,685,808 ha) has a low, medium, and high environmental health risks assessment. The study also shows for environmental health mapping, only the criteria of flood risk, environmental health vulnerability, and environmental health capacity are enough to obtain reliable maps. And the novelty of this research is based on the concept that shows how to multiple combined methods to assess environmental health risk. Taking into account these changes, the proposed model could perform future risk assessments.

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