A Spatial Study on Risk Analysis of Disasters Caused by Natural Hazards to Cultural Heritage in Indonesia

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Cultural heritage is at risk of disasters caused by natural hazards, especially in growing countries, such as Indonesia. By adopting the Taboroff's concept of risk analysis (hazard, control mechanism, and receptor), this study spatially examines the risks of natural hazards to cultural heritage. This approach is applied to identify areas need to be prioritized in mitigation by at least including disaster risk reduction (DRR) in their spatial plan. This study confirms that regions with high proportions of cultural heritage inventory are also highly exposed to natural hazards. However, this study also shows that those areas do not necessarily have a disaster mitigation-based spatial plan.

Keywords: *risk analysis, natural hazards, cultural heritage, disaster mitigation-based spatial plans*

1. Introduction

Cultural heritage which is the legacy of physical artifacts and intangible attributes of a society or group around the world that are inherited from past generations, and need to be preserved in the present and bestowed for the advantage of future generations[1)], due to various reasons such as climate change, natural hazards, wars, etc. is incessantly destroyed from time to time. Fires, earthquakes, flooding, tsunami, winds, land and mudslides, and tropical storms are among the dominant causes of loss and damage[2)]. In response to this issue there has been a growing awareness of the need to protect cultural resources ranging from archaeological sites containing pre-historic data and more recent information to individual historic buildings to museum collections even to entire rows[3)]. However, in growing countries, although evidence points to a pattern of higher vulnerability, there is still a weak record of implementation of protective measures to control or limit the damage and prolong recovery time[4)].

One way to mitigate disasters caused by natural phenomena is through land-use planning or spatial planning. Some scholars assume that this kind of plan can achieve the long-term reduction of community's vulnerability to multiple hazards[5-7)]. The latest framework of DRR, the Sendai Framework 2015-2030 mentioned on its second priority the recommendation of incorporating the risk reduction into land-use planning and management practices as well as improvements in spatial planning, especially at the local level.

Since the risks of cultural heritage to natural hazards are location dependent[4)], a spatial approach could help in delivering more spatial dimensions of risks to these assets. A spatial dimension provides the arena for the overlapping of multiple risks in particular places. Spaces may be addressed both as an analytical framework for the study of risk, and as an empirical tool for risk management, based on localizing, measuring, regionalization, and mapping of risks[8)].

Considering the significance of spatial approach and due to the limitations of studies about disaster mitigation of cultural heritage from a spatial perspective, this study, therefore, attempts to spatially assess the risks of disasters caused by natural hazards to cultural heritage in Indonesia, by adopting the Taboroff's concept of risk analysis (hazard, control mechanism, and receptor)[4)]. By using descriptive spatial analysis, this paper aims to evaluate areas with high exposure of natural hazards but rich in cultural heritage assets in Indonesia whether they have been prepared to disasters by formulating a disaster mitigation-based spatial plan as a mitigation measure.

The primary question of this study is how areas with high numbers of cultural heritage assets and areas highly exposed to natural hazards are spatially distributed (hazard and receptor analysis)? The following question is how far mitigation efforts in which in this study is represented by the availability of a disaster mitigation-based spatial plan, have been applied in areas that are rich of cultural heritage properties but highly exposed to natural hazards (control mechanism analysis).

In answering those questions, this paper is structured as follows. The next section brings a brief overview of cultural heritage and trends of disasters caused by natural phenomena in Indonesia. The third segment provides an overview of disaster mitigation-based spatial planning. The following section outlines the methodology applied in this study, while section five discusses the findings and the last section concludes this study and recommends some policies.

2. Cultural Heritage and Natural Hazards in Indonesia

There are 1,073 properties listed in UNESCO's World Heritage List, of which most sites come from cultural and natural categories, 832 and 206 respectively[1)]. These sites are classified into five geographic zones: 1) Africa, 2) the Arab States, 3) Asia and the Pacific, 4) Europe and North America, and 5) Latin America and the Caribbean. In 2018, from hundreds of heritage sites in Indonesia, 27 were selected to be part of global assets, in which eight that of was adopted by UNESCO on the World Heritage List as part of the Asia and Pacific heritage and the remaining 19 sites are part of UNESCO's Tentative List. World cultural heritage sites from Indonesia are Borobudur Temple Compounds, the Subak System as a Manifestation of the Tri Hita Karana Philosophy, Prambanan Temple Compounds, and Sangiran Early Man Site. Meanwhile, nationally, there are 113 cultural heritage properties have been approved and designated as part of National Cultural Heritage[9)]. Cultural Statistics of Indonesia 2017 cites that there are 998 cultural heritage, 7,238 intangible heritage, 652 local languages and thousands of traditional knowledge and expressions[10)]. In 2018, there are 31,012 items registered as cultural heritage properties ranged within five categories, from objects to areas/sites[9)].

The management and protection of cultural heritage in Indonesia are under the authority of the Ministry of Education and Culture of Republic of Indonesia (MEC) and is regulated under Law 11/2010 on *Cagar Budaya* or Cultural Property Conservation (CB 11/2010). This law compared to its predecessor (Law 5/1992) brings new aspects of cultural property management, such as categorization, decentralization of heritage register (national, provincial, and municipal), and a multidisciplinary approach in heritage conservation work[11)]. Furthermore, this law also restructures the national inventory into four stages (registration, verification, appraisal, and designation) before giving an object ID number.

Despite some advancements in the content of CB 11/2010, some experts and scholars view this law is inadequate enough to ensure the safeguarding of Indonesia's cultural heritage. This fundamental law is criticized for its inability also to highlight the importance of protecting intangible cultural heritage, its narrow definition of each category of cultural heritage, and the absence of explanation about the meaning and concept of the value of a designated heritage[11)]. Also, CB 11/2010 is still applying the old paradigm of cultural heritage conservation which depends on government and misses the concept of active involvements of the community[12)]. Last, this law has not also been integrated with land-use or spatial planning and disaster management. Those matters are exacerbated by the lack of government regulations and other derived regulations of which more operationalized guidelines are further be addressed.

Besides the issues of legislation and management as abovementioned, one of the main problems faced by the cultural heritage preservation in Indonesia is the high exposure to natural. This country is ranked as one of the most disaster-prone countries due to its high exposure to a series of natural and climate hazards as well as significant social vulnerabilities[13)]. World Risk Report 2017 ranked Indonesia as the 33rd high-risk country globally with World Risk Index (WRI) of 10.49%. Vulnerability level, lack of coping and adaptive capacities are the factors behind this considerable risk index (54.19%, 80.94%, and 49.27% respectively)[14)]. According to EM-DAT (the Emergency Events Database), there have been 458 disasters caused by geophysical, hydro-meteorological, and climatological hazards with around 230,000 tolls and 30 million affected people[15)]. However, according to BNPB *(Badan Nasional Penanggulangan Bencana)* or Indonesian National Agency for Disaster Management, the number of affected people is higher[16)]. Flooding, earthquakes, and volcanic activity are among the most frequent events as well as the most damaging events with earthquakes as the deadliest one (around 70% of deaths caused by these catastrophes)[15)]. Statistics from DIBI (*Data dan Informasi Bencana Indonesia*) or Indonesia's Data and Information of Disaster show that in the past ten years there have been significantly increasing frequencies for flood, landslide, and storm (**Fig. 1**). When seeing these events geographically, three provinces in Jawa, namely Central Jawa, West Jawa, and East Jawa, have the most persistent disasters, although Aceh and two other regions in Sumatera those with the highest risk of disasters in Indonesia (**Table 1).**

Due to the rare availability of historical archives on the number of heritage assets ruined by disasters, it is somewhat difficult to provide the information on how disasters have been significantly damaged heritage assets in Indonesia. However, some studies recorded how massive disasters such as the 2006 Yogyakarta earthquake, the 2009 Padang earthquake, and the 2010 Mount Merapi eruption severely damaged cultural heritage properties[17-20]. While the quake mostly affected the structures, volcanic eruptions ruined the sites by a thick ash cover. When Mount Merapi erupted, the Borobudur Temple was shrouded with the destructive ash, which hindered the drainage system and penetrated the temple through the cracks and gaps in the stones. In case of earthquakes, the 2006 Yogyakarta earthquake, caused structural damages to various cultural heritage sites, especially the temples from the Prambanan World Heritage Compounds. Other cultural sites sustained injuries, such as Taman Sari Water Castle, the Sultan's Palace in Yogyakarta, as well as the popular Kasongan pottery village. The same situation also happened for 21 heritage assets in Padang due to the 2009 earthquake. Consider those figures of damaged cultural heritage assets and the frequencies of disasters, disaster mitigation for cultural heritage should also be prioritized in disaster management in Indonesia. However, in fact, although there have been many improvements in DRR and preparedness, including risk governance in Indonesia after the 2004 Indian Ocean Tsunami[13], the issue on disaster mitigation of cultural heritage as well as the cultural preservation itself still has not been the main priority. There have been limited mitigation policies on this issue, which is then presumed will lead to significant losses of these assets in the future. The main foundations of disaster mitigation for cultural heritage themselves, the Law 24/2007 concerning Disaster Management (DM 24/2007) and CB 11/2010, do not explicitly mention framework, system, actors and standard operating procedure in safeguarding and making recovery of cultural heritage in case of disaster.

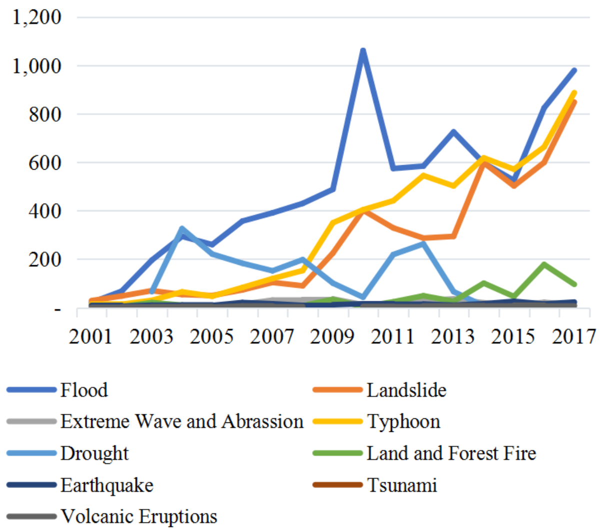


Fig. 1 Number of Disasters from 2001 to 2017
Source: The Author, data analyzed from DIBI

Table 1 Ten Provinces with the Most Frequent Disaster Events caused by Natural Hazards (from 1815 to 2018) compared to the Multi-Hazard Risk Index

Province	Number of Occurrences	Rank of Multi-Hazard Risk Index 2013
1. Central Jawa	5,334	13
2. West Jawa	3,559	12
3. East Jawa	3,143	15
4. Aceh	894	1
5. South Sulawesi	875	26
6. North Sumatera	750	2
7. West Sumatera	739	3
8. East Kalimantan	636	23
9. South Sumatera	607	6
10.East Nusa Tenggara	582	19

*Source: The Author, data analyzed from DIBI and IRBI (*Indeks Risiko Bencana Indonesia*) or Indonesian Disaster Risk Index 2013*[21]

3. Disaster Mitigation-Based Spatial Planning

Natural phenomena are not a disaster if human beings do not interfere natural environment; however, as the civilization progressed, interactions between natural and developments or urban environments become inevitable, and it can cause a disaster[22]. Since land-use pattern can depict the interactions between natural and urban environment, a risk-based land-use plan can play an essential role in DRR. In Indonesia, land-use planning is part of the spatial planning and is managed under the Law 26/2007 concerning Spatial Planning. This law and DM 24/2007 require local governments to implement DRR in their spatial planning actively.

A spatial plan in this country is comprehensive enough as it includes how cultural heritage sites, in general, should also be spatially controlled and utilized as part of the conservation areas in the spatial pattern plan section[23]. Thus, this plan can be viewed as a non-structural mitigation measure of natural hazards to cultural heritage when its content has incorporated with DRR principles, in which in this study is called as a disaster mitigation-based spatial plan. However, the limited availability of disaster-related spatial data, such as bigger scale or more detail hazard maps has hampered the formulation process. Thus, there should be improvements in local spatial plans regarding disaster mitigation and disaster risk reduction including the need for integrated disaster-related spatial data as a fundamental element of policy formulation[24].

4. Methodology

(1) Data Collection

This study mainly utilizes data taken from Cultural Statistics of Indonesia 2017 published by the MEC[10)] which provides an overview of cultural heritage in Indonesia, including numbers of cultural heritage based on CB 11/2010 for each province. Furthermore, this study also mines data from https://cagarbudaya.kemdikbud.go.id/. This online database provides data and information about cultural heritage assets in Indonesia, particularly those that already have been designated, which are equipped with pictures and geospatial references. In addition, data about the presence of world heritage assets is obtained from http://whc.unesco.org/en/statesparties/ID.

Table 2 Variable and Indicator of the Risk Analysis

Component	Variables	Indicators	Classification of Indicators/ Variables	Score	Total Score for the Component
Hazard	Variety	Variety of the existed natural hazards with high risk	**Very High:** 5 or more; **High:** 4 **Moderate:** 3; **Low:** 2; **Very Low:** 0-1.	1-5	· Max. Score: 20 · Min. Score: 4
	Severity	The proportion of an area categorized as a highly prone to multiple natural hazards to the total area of a province	**Very High:** 25% ≥ x; **High:** 20% ≤ x < 25%; **Moderate:** 15% ≤ x < 20%; **Low:** 10% ≤ x < 15%; **Very Low:** x < 10%.	1-5	
		Number of the damaged building (houses and public facilities) resulted from disasters caused by natural phenomena (1815-2017)	**Very High:** 300000 ≥ x; **High:** 225000 ≤ x < 300000; **Moderate:** 150000 ≤ x < 225000; **Low:** 75000 ≤ x < 150000; **Very Low:** x < 75000.	1-5	
	Frequency	Frequencies of disasters caused by natural hazards (1815-2017)	**Very High:** 2000 ≥ x; **High:** 1500 ≤ x < 2000; **Moderate:** 1000 ≤ x < 1500; **Low:** 500 ≤ x < 1000; **Very Low:** x < 500	1-5	
Receptor	Designated Properties	Number of Designated Cultural Heritage Properties	**Very High:** 120 ≥ x; **High:** 90 ≤ x < 120; **Moderate:** 60 ≤ x < 90; **Low:** 30 ≤ x < 60; **Very Low:** x < 30	1-5	· Max. Score: 12 · Min. Score: 2
	Registered Properties	Number of Registered Cultural Heritage Properties	**Very High:** 2000 ≥ x; **High:** 1500 ≤ x < 2000; **Moderate:** 1000 ≤ x < 1500; **Low:** 500 ≤ x < 1000; **Very Low:** x < 500	1-5	
	Critical Properties	Presence of World Heritage	**Yes:** 1; **No:** 0	0-1	
		Presence of National Heritage	**Yes:** 1; **No:** 0	0-1	
Control Mechanism	Quality of Disaster Mitigation-Based Spatial Plan	The score of the Quality of Disaster Mitigation- Based Spatial Plan	On the Graph: **Very High:** 3.2 ≥ x; **High:** 2.4 ≤ x < 3.2; **Moderate:** 1.6 ≤ x < 2.4; **Low:** 0.8 ≤ x < 1.6; **Very Low:** x < 0.8	1-5	· Max. Score: 5 · Min. Score: 1
			On the Map: Natural Breaks		

Source: The Author, 2018 adopted from Taboroff (2000), Shaw et. al. Kusumastuti (2014), and Wibowo et al. (2015)

Moreover, a web-based database named DIBI and data obtained from MSPA are used to analyze the exposure of natural hazards to cultural heritage in this study. The data sourced from DIBI can be accessed from http://dibi.bnpb.go.id/dibi/. Users can view and extract data on past hazardous events, human and economic hazard exposure and the risk of different natural hazards. Meanwhile, secondary data taken from the MSPA's report are about the variety of natural hazards in each province and the percentage of areas in a province which are high risks to the natural hazards[24)]. Next, to analyze how disaster mitigation has been applied to anticipate the high exposure of natural hazards to cultural heritage, the quality of disaster mitigation-based spatial plans are used as an indicator. Data for this variable sourced from the similar abovementioned MSPA's report. In this report, there is a section which examines the quality of General Spatial Plan or RTRW (*Rencana Tata Ruang Wilayah*) of each province in Indonesia related to the incorporation of disaster risk reduction on that plan and transforms the level of the quality into scores. Each jurisdiction is scored based on 19 components with the maximum score is 4. The higher the score, the better the mitigation quality of that spatial plan.

(2) Operationalization

An initial yet very significant phase of disaster mitigation is risk analysis. It is necessary to establish and articulate clear disaster mitigation policies concerning a variety of items at risk[2)]. This paper applies a risk analysis concept adopted from Taboroff's which comprises hazard, control mechanism, and receptor (target)[4)]. This concept is as same as the general risk assessment which consists of hazard, capacity, and vulnerability. The difference is mainly on the vulnerability in which in this concept is called the receptor. Receptor here refers to a historic town, museum, or archaeological sites. Since this study generalizes the hazard assessment, thus hazard is measured as a general exposure which consists of variety, severity, and frequency[25,26)]. **Table 2** above summarizes variables and indicators used in this study.

There are two phases of analysis in this study. The initial step is the calculation of each component of risks, while the second one is the visualization process by translating the scores for each element into maps. First, each of them is measured by the sum of its variables. This scoring aims to analyze which areas have a higher level of exposure to the natural hazard and which of those that should have more prioritized mitigation policies due to their number cultural heritages and presence of important heritage such as world and national heritage. Finally, they are cross-checked with the availability of disaster mitigation-based spatial plans. Once all components are scored, the scores are then visualized into choropleth maps with a natural break (Jenks) classification to see how they are spatially distributed across provinces. As the base map, this study makes use of an administrative map obtained online from http://portal.ina-sdi.or.id/.

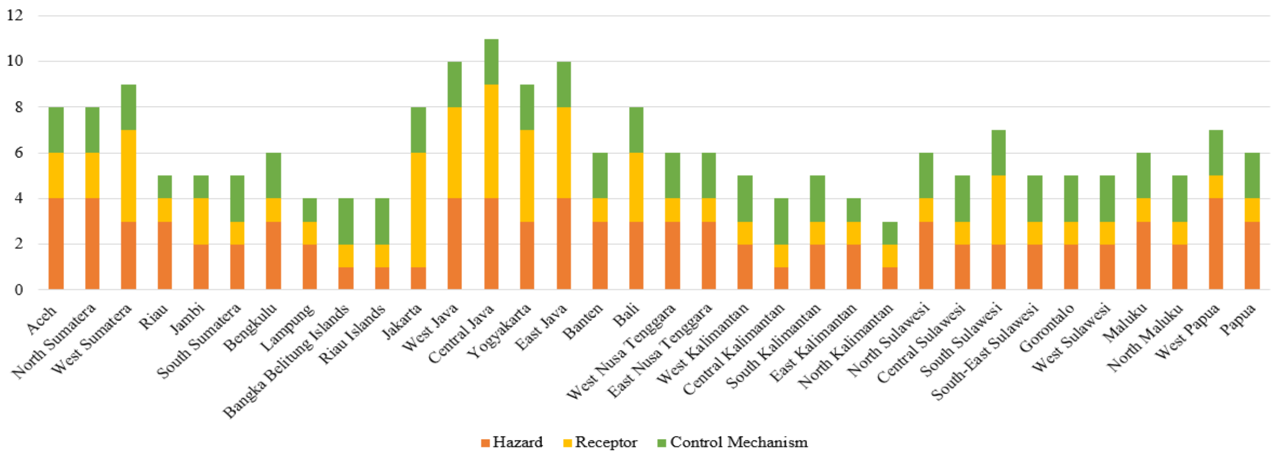


Fig. 2 Comparison of the Scores for each Component of Risk Analysis
Source: The Author (2018)

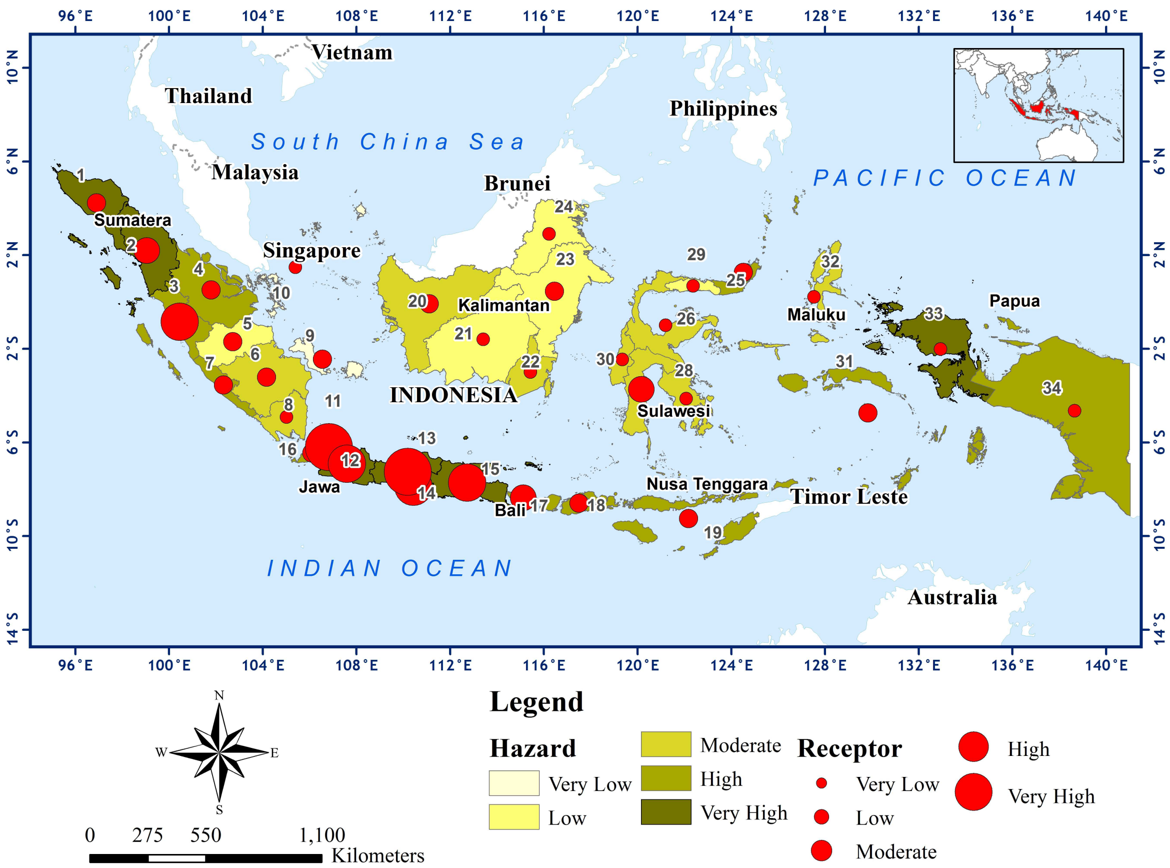
5. Findings and Discussion

(1) Comparison of Scores for each Component of Risks

The bar chart in **Fig. 2** illustrates how each component contributes to the total risk of natural hazards to cultural heritage in every province in Indonesia. Look further at the graph, in general; there are two regions with a high combined score of risk, Sumatera, and Jawa. While provinces in Jawa have high-risk scores attributable to their high hazard and receptor scores, high scores of provinces in Sumatera mostly due to their high hazard scores. Most areas in Jawa start from Jakarta up to East Jawa are those with the highest score for the combination of risk components, while provinces in the Kalimantan Region tend to have the lowest one. Specifically, the highest score of the receptor component is that of Jakarta, West Jawa, Central Jawa, Yogyakarta, and East Jawa. In case of the Sumatera Region, there are three provinces with a high risk of natural hazard to cultural properties, namely Aceh, North Sumatera and West Sumatera. As opposite hazard and receptor components, the component of the control mechanism as can be seen on the graph is not as varied as that other two components. Almost all provinces have a similar score of the control mechanism, except for Riau, Jambi, Lampung, East and North Kalimantan.

(2) Spatial Distribution of Scores for each Component of Risks

This subsection describes how each component of natural hazard risk to cultural heritage properties in every province ranges spatially. While **Fig. 3** shows how areas highly exposed to natural hazards and where cultural heritage properties are most likely to reside spatially distributed, the map on **Fig. 4** spatially depicts provinces with high level of presence of these heritage assets ranges but highly vulnerable to disaster. Thus, the first question of this study is answered by **Fig. 3**, while **Fig. 4** responds the second one.



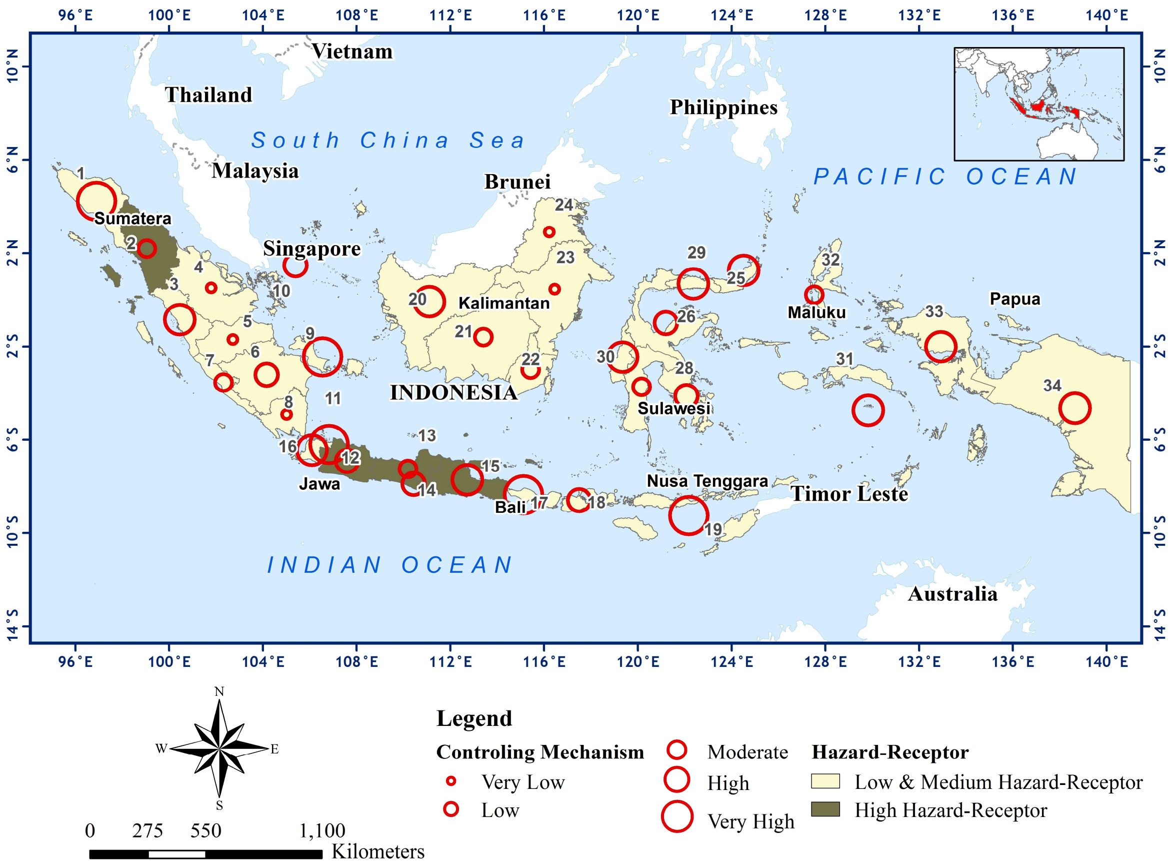
1. Aceh
2. North Sumatera
3. West Sumatera
4. Riau
5. Jambi
6. South Sumatera
7. Bengkulu
8. Lampung
9. Bangka Belitung Islands
10. Riau Islands
11. Jakarta
12. West Jawa
13. Central Jawa
14. Yogyakarta
15. East Jawa
16. Banten
17. Bali
18. West Nusa Tenggara
19. East Nusa Tenggara
20. West Kalimantan
21. Central Kalimantan
22. South Kalimantan
23. East Kalimantan
24. North Kalimantan
25. North Sulawesi
26. Central Sulawesi
27. South Sulawesi
28. South-East Sulawesi
29. Gorontalo
30. West Sulawesi
31. Maluku
32. North Maluku
33. West Papua
34. Papua

Fig. 3 Spatial Distribution of Natural Hazard and Receptor Component
Source: The Author, Analysis, 2018

Fig. 3 shows that the northwestern part of Sumatera Island, all part of the Jawa Island, and West Papua are those with a high level of natural hazards. The Island of Kalimantan and Sulawesi tend to be a safer region. Jawa is the most inhabited island in Indonesia, almost one-third population of this country reside here. However, this island is also a home of various natural hazards, especially floods, landslides and volcanic eruptions. This island is also very vulnerable to the sea-level rise in its coastal areas. Next, seeing the bullet pattern of the receptor component, Jawa Island is the only island with the highest level of the receptor. This situation is mostly related to the high numbers of registered cultural properties in this region as well as the existence of National and World Cultural Heritage Sites. Post-colonialism buildings temples are those mostly characterized cultural heritage assets in Jawa. Central Jawa and Yogyakarta are the home of Hindu and Buddhist temples in Indonesia. Meanwhile, Jakarta and West Jawa have several museums and post-colonialism buildings.

While in **Fig. 3** hazard and receptor component are represented individually, in **Fig. 4** those components are mixed and transformed into two categories. Areas with high scores of hazard and receptor (including very high and high) are in the first category and have a darker shade on the map, while other than that is classified as "low and medium hazard-receptor" and is lightly colored. From this reclassification, there are only five provinces labeled as high hazard-receptor areas, namely North Sumatera, West Jawa, Central Jawa, Yogyakarta, and East Jawa. A layer of the spatial distribution of the control mechanism is then superimposed to find out how a disaster mitigation-based spatial plan has been adopted in those areas.

Interestingly, four out of five provinces classified as high hazard-receptor areas, have low scores of the control mechanism components. This situation means that they have not well-anticipated their high exposure to hazard characteristics yet through disaster mitigation-based spatial plans. More upper control mechanism components indeed are those of low and middle hazard-receptor. As seen on the map, Aceh, West Sumatera, Jakarta, Bali, and East Nusa Tenggara are those with more disaster mitigation principles adopted on their spatial plans. In case of Aceh, it is entirely understandable why does this province has a high score on this component. The 2004 Indian Ocean Tsunami which severely impacted Aceh, should have brought more considerations on spatial planning besides more data are also available after disaster since there have been many post-disaster studies that conducted by national and international researcher or organization. The same situation might apply to West Sumatera. This province presumably has a more disaster focus spatial plan since it experienced one of the devastating earthquakes in Indonesia, the 2009 Padang Earthquake. This situation is supported by a study conducted by Rachmawati which found that municipalities that have experienced major disasters tend to have more detailed contents of disasters on their spatial plan due to the more available disaster-related spatial data due to the additional data supply from the central government, NGOs, and academic institutions[23]. In case of Jakarta, it is logical the control mechanism is also high since this province is the capital city of Indonesia, where most of the data, information, and sources are available here.



1. Aceh
2. North Sumatera
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19. East Nusa Tenggara
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26. Central Sulawesi
27. South Sulawesi
28. South-East Sulawesi
29. Gorontalo
30. West Sulawesi
31. Maluku
32. North Maluku
33. West Papua
34. Papua

Fig. 4 Spatial Distribution of the Component of Controlling Mechanism compared to Hazard-Receptor
Source: The Author, Analysis, 2018

6. Conclusion and Policy Recommendation

As cultural heritage is at risk of natural hazards, improvement in mitigation efforts is inexorable. This study approves that areas with a high number of cultural heritage inventories are also the location of the natural hazard-prone areas. Moreover, findings demonstrate that provinces with the considerably a high hazard-receptor score do not necessarily have a more disaster-oriented spatial plan. However, it should also be considered that those areas perhaps prefer to have more structural disaster mitigation strategies.

Ideally, in areas with a high degree of predictability of disasters, the policy should emphasize systemic answers over specific actions that should be taken based on the recognition of hazard and risk. This takes into account the consideration on what policies that relate to different phases of disasters – pre-event, crisis and post-event periods; strategies on the impacts on various kinds of elements comprising the risk situation; the relationship of the method of different organizations to each other[2)]. Therefore, it is suggested that clear policies concerning a variety of items at risk should first be established, especially in areas cultural heritage properties are highly exposed to natural hazards. Furthermore, a better quality of disaster mitigation-based spatial plan should be formulated, which entirely includes the availability of more specific hazard and risk maps, hazard identification, evacuation point and evacuation route plan and control of spatial utilization (general building codes, zoning overlays, post-disaster land use change, etc.).

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