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Advances in Climate Change Research 8 (2017) 286–296

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Vulnerability assessment: A comparison of three different city sizes in the coastal area of Central Java, Indonesia

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1. Introduction

Urban expansion occurs as increasing population of people agglomerate in an urban area. According to United Nations (UN, 2006), almost 60% of people will live in cities by 2030. World Bank (WB, 2014) reveals that by 2025, there will be 68% of people living in Indonesian cities and that this projection will increase up to 82% by 2045. This will be much higher than the world's average. Urbanization is an important issue in Indonesia's development. It's consequences can be seen in the increasing built-up areas and population density in Indonesia (Handayani and Kumalasari, 2015). The increasing population pressure has created additional stress and pressure on the urban environment. This is evidenced by the more intense climate related and climate change hazards experienced in Indonesia today (Taylor, 2015; Djalante and Tomalla, 2012). As a result, the complexity of urbanization goes beyond population pressures, but poses hard and soft infrastructure pressures. This is especially the case in Indonesia because 60% of the populations are living in coastal area, and therefore, are prone to climate change hazard (Kumar et al., 2016;

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Peer review under responsibility of National Climate Center (China Meteorological Administration).

https://doi.org/10.1016/j.accre.2017.11.002

Solecki et al., 2015; Takagi et al., 2014; McGranahan et al., 2007).

There is evidence that increase in population results in increase in the level of vulnerability of the coastal area due to impact of climate change (Kumar et al., 2010; Sales Jr., 2009; Torresan et al., 2008). Sea level rise and coastal erosion are the most common climate change phenomena that lead to frequent hazardous events (especially flood) due to higher tides and higher river flows (McGranahan et al., 2007). Even though, some scholars (Handayani and Kumalasari, 2015; Malalgoda et al., 2014; Huong and Pathirana, 2013; Dickson et al., 2012; McGranahan et al., 2007) assert that infrastructure failure such as bad drainage system is the main cause of flood in many growing cities in Asia, sea level rise as an obvious climate change phenomena also poses serious threats to coastal cities. This study recognizes vulnerability assessment as an important tool that could be used to enable policymakers gain the appropriate data necessary for reducing risks emanating from climate change in cities (Kumar et al., 2016).

Vulnerability assessment is a common tool for signifying the potential occurrence of harm within human and ecological systems in response to climate change (Adger et al., 2007). Preston et al. (2011) states the importance of mapping the degree of vulnerability to enable the production and representation of local context scenarios. There are a lot of ways for making robust and reliable vulnerability assessment (Kumar et al., 2016; Shah et al., 2013; Birkmann et al., 2013; Preston et al., 2011; Eriksen and Kelly, 2007). However, Eriksen and Kelly (2007) note that there is still a lack of theoretical and conceptual frameworks for choosing appropriate indicators for assessments. Preston et al. (2011) reveal scale issues as one critical point for clarity of assessments. Most vulnerability assessments are done at national and regional levels (mainly due to data availability at those levels), even though such assessments are conducted a local levels – hence, needs strong local orientation (Kumar et al., 2016; Rasch, 2015; Preston et al., 2011; Eriksen and Kelly, 2007). This study elaborates, using the most possible secondary data in the lowest level of administrative boundary in Indonesia (referred to as *kelurahan* or urban village) to derive local orientations for assessments. The study is in line with Rasch (2015) who assessed urban vulnerability in Brazilian municipalities and Kumar et al. (2016) who conducted a similar assessment in Bangalore (India). Both studies elaborated assessments at the local levels. Their limitations are the lack of comprehensive indicators because of low quality data and inconsistencies in data. By using the most possible secondary data in the lowest level (instead of the national level), this study is an improvement on the previous work done on this subject in Asia, especially in Indonesia.

Considering the linkage (and importance) of connecting urbanization phenomena and vulnerability assessments, this paper explores the vulnerability assessment of three different city sizes in the northern coast of Central Java province. It compares vulnerability levels based on the sizes (that is, levels of urbanization) of the cities under investigation. High population density and different availability of infrastructures and other supporting facilities have made the coastal urban areas to become the most dynamic areas in Central Java (Handayani and Kumalasari, 2015; Marfai et al., 2008). As a way forward, the study also elaborates the extent to which the intensity or concentration of development activities in the different cities relate to their vulnerability levels.

2. Study area

Three cities were selected in the northern coastal area of Central Java for this study. They are the cities of Semarang, Tegal, and Lasem. These cities were selected because they represent varying levels of urbanization and they are situated within evenly dispersed locations along the coastline—hence, their different city sizes make them suitable for comparative vulnerability assessment. In addition, the three cities experience significant climate change hazards.

Semarang city is a metropolitan city located in the middle part of the seashore in a province inhabited by 1.5 million people. Tegal city is an intermediate or medium-sized city in the western part inhabited by 0.24 million people. Lasem represents a small-sized city located in the eastern part with less than 35,000 inhabitants. Fig. 1 shows the location of the three cities with a description of their main characteristic. The strategic locations of these cities encourage the concentration of human settlements. Hence, these locations are sites of intense urbanization and are prone to natural hazards—such as flood, landslide, drought, and tidal flood.

3. Data and method

3.1. Data

Assessment of vulnerability has been applied in various sectors to address environmental issues, hazards or climate change impacts (Kumar et al., 2016; Rasch, 2015; Yoo et al., 2014). Apart from its comprehensive application in multisectors, more specific sectoral assessments have been conducted within the transportation sectors (Szendrö et al., 2014) and tourism sectors (Csete et al., 2013). These two specific applications provided basic principles for the vulnerability assessment calculation method used in this study. Alongside the conceptual framework suggested by the IPCC (1995), the assessment done in this study was calculated based on three components: exposure, sensitivity, and adaptive capacity. Furthermore, due to the complexity and the need to involve different indicators, most of the assessment results were simplified by using indexing system.

Vulnerability assessment is also closely related to adaptive capacity measurement which is used to indicate capability for a system to adapt. The indexing approach for measuring the capacity, usually called Adaptive Capacity Index (ACI), has been applied in various ways and for various purposes. According to Alessa et al. (2016), ACI initially applied to adaptive measurement by combining economic and ecological aspects stated in the United Nations Office for Disaster Risk Reduction's (2005) Report on building resilience to deal with

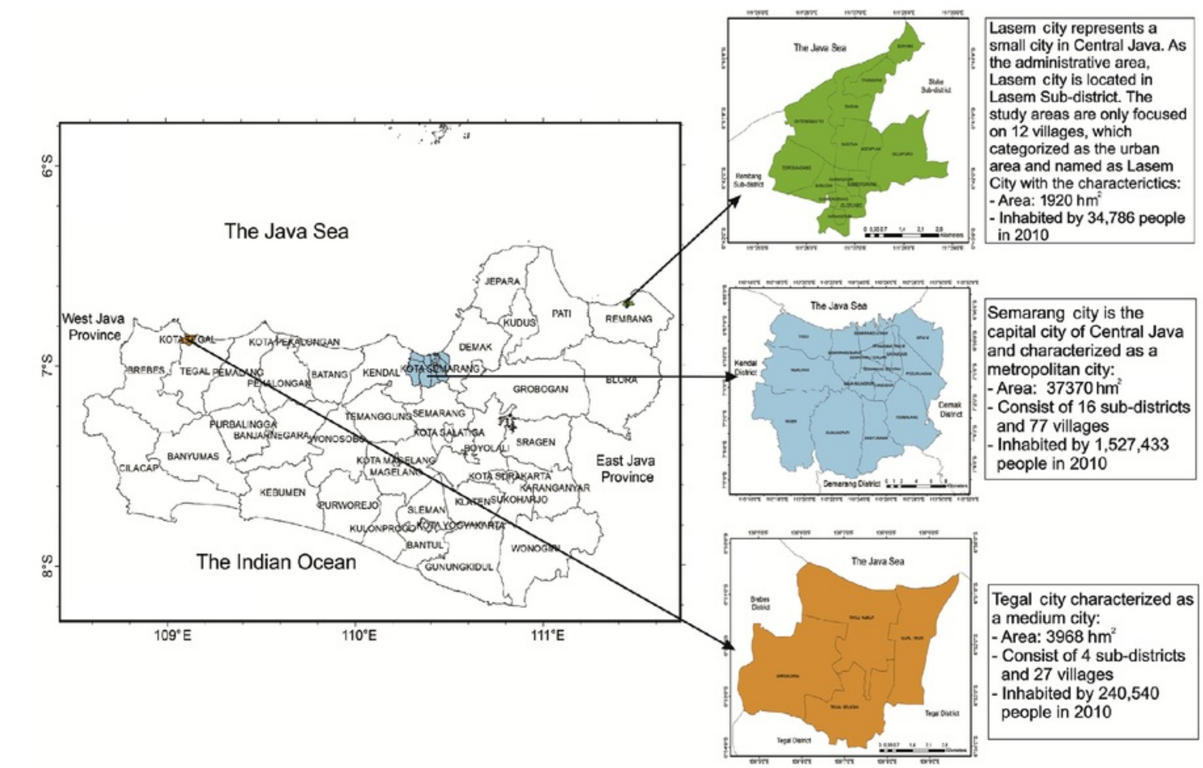

Fig. 1. Study areas.

disasters (http://www.unisdr.org/2005/wcdr/wcdr-index.htm). The ACI is commonly applied to macro (national) level measurements (Vincent, 2007). However, the approach has been used for various purposes at micro level (i.e. individual and communities levels). Alessa et al. (2016) used ACI to measure the adaptation of people for community-based early warning system in the Arctic by combining physical and social indicators. Also, the ACI has been used by Olson et al. (2011) to measure adaptive capacity of people who have been diagnosed with advanced cancer. The study analyzed the data at the individual level by using descriptive and inferential statistics.

Accordingly, various approaches have been used by different researchers in measuring capacity indexes has been elaborated in the context of vulnerability assessment. Yoo et al. (2011) develops vulnerability assessment for coastal cities. Based on a case study of Busan (South Korea), Yoo et al. (2011) showed vulnerability index (VI) from exposure, sensitivity, and adaptive capacity for three types of climate change hazards, namely sea-level rise, heat wave and heavy rainstorm. Similarly, Yoo et al. (2014) has also demonstrated Environmental Vulnerability Index (EVI) in Jakarta, Indonesia using physical, socio and economic indicators which were categorized into environmental exposure, sensitivity, and adaptive capacity. Taking a different approach, Csete et al. (2013) used indexing system to explore climate change vulnerability of tourism in Hungary by elaborating on the exposure, sensitivity, and adaptive capacity indicators in scale. Szendro et al. (2014) elaborated on the adaptive capacity of Hungarian road transport by using Sectoral Adaptive Capacity Index (SACI). The resultant indexes (values between 0 and 1) provided better illustration of complex indicators applied in the calculation.

Following previous studies that have been using indexing approaches, this study compares the levels of vulnerability among the three different urban characteristics as explained in Fig. 1. Exposure refers to the magnitude of hazard, consisting of the frequency and severity of a system in the form of either the population or property (Füssel and Klein, 2006; Rasch, 2015). Sensitivity reflects how the system responds to climate change (Wu et al., 2012). Adaptive capacity is defined as the ability of the system to cope with the impact of hazards through its local sources and condition (Adger et al., 2005). Higher level of sensitivity and exposure indicate that the system is more easily prone to having an adverse impact on climate change or the system is more vulnerable. In contrast, the higher level of adaptive capacity shows that the system is less vulnerable. As have been demonstrated by earlier studies (Kumar et al., 2016; Rasch, 2015; Yoo et al., 2014), differences in socio-economic characteristics, infrastructure provision, and governance affect the level of vulnerability. Furthermore, each region has a different degree of vulnerability that is determined by its type of hazards and their impacts.

In general, there are two indexes that indicate vulnerability levels, namely ESI and ACI. ESI relates to the population, property, and livelihood that might be susceptible to the climate change impact. ACI entails the local resources of a system, e.g. the capacity and the availability of infrastructures and facilities to cope with the impact of hazards. The chosen indicators are grouped into categories later analyzed to indicate their contributions to ESI and ACI. The data for this study were obtained from existing literature on the subject, as well as primary sources. Table 1 explains the selected indicators of ESI and ACI.

3.2. Method of vulnerability assessment

The unit of the analysis for the vulnerability assessment is the urban village (locally referred to as *kelurahan*) which is the lowest administrative area. Mix methods, both quantitative and qualitative are applied. The quantitative analysis was used as a scoring technique—involving weighting each indicator of vulnerability. The qualitative analysis was used to determine and verify the weight of each vulnerability indicator through Focus Group Discussion (FGD) with relevant stakeholders/local expert.

Weighting is critical as it represents relative importance among indicators applied. According to Tate (2012), equal weighting is the most common approach in measuring vulnerability mostly in social context mainly because of the lack of information about the importance of an indicator compared to others. However, in view of the importance of specific comprehension on the site, vulnerability also signifies relative situation by considering particular people and places (Luers, 2005; Ahsan and Warner, 2014), expert judgment is then also generally used to weight the indicators (Tate, 2012). Accordingly, an FGD was conducted with the stakeholders from each city to weight the indicators of ESI and ACI of those initially identified from literatures. The weight of each indicator and data was discussed and verified with the key stakeholders. They are representatives of local government, local organizations and local academicians who are knowledgeable about the area and have a concern on climate change issues. This technique was used to reach a consensus on the adjusted weightings of the characteristics of a city. The weight is given according to the degree of importance based on the key stakeholders' perceptions. In this regard, more sensitive indicators (such as one that has the capacity to produce greater impacts on the adaptation) were given higher values, and vice-versa. Even though expert judgment may lead to subjective assessment, the consensus resulted from the process and the intention to set the final result as policy recommendation is the advantages to ensure the validity and the acceptability of the final result.

The data obtained from the secondary sources were from census document, and village potential document (called as *potensi desa* or *PODES*). The time period of analysis is limited to 2010 because the year of 2010 was the year of the latest census and therefore, provides higher data validity. The levels of vulnerability were assessed through the following steps:

1) Identifying and defining vulnerability indicators and data: The vulnerability indicators and data obtained from the literature review and then adjusted to the availability of data. Refer to Table 1 for details of the two categories (ESI and ACI) of indicators used.
2) Weighting each of vulnerability indicators and data: Weight is the value given to each indicator and data of ESI and ACI. The value of each data ranges 0–1 in scale, thus, the total weight of either ESI or ACI is 1. The weight of each indicator and data are explained in Table 1.
3) Calculating the vulnerability data: The purpose of calculating the data was to derive the actual value of each data. The calculating process is conducted using two methods, the ratio method and scoring method. The ratio method entailed dividing the value of each data by the other compatibility data. For example, the population density is the ratio between populations to the total area of a village, vulnerable people is the result from a division between the number of vulnerable people (women/children/elderly) divided by the total population of a village. The scoring method is used for indicators include the indicators of built-up area, fish pond and rice field, vulnerable people, population density, poor living, livelihood, and house types. Scoring method was used for some indicators, such as educational level, clean water source, sanitation, the number of educational facilities, and the number of health facilities. Refer to Table 1 for details of the methods used for each data.
4) Standardizing each of the results from the calculations: Standardization is a process used for normalizing the actual values or scoring values into 0 to 1 scale to make it more comparable. The normalizing process was executed using the following formula:

$$\text{Normalized value} = \frac{\text{actual value or scoring value}}{\text{maximum value}}. \qquad (1)$$

5) Calculating the weight of each data: After each of the values (based on calculating process) has been normalized, the result is multiplied by the weight. After all of the data have been multiplied by the weight, the weighted data and indicators of ESI and ACI is summed to obtain the final value of ESI and ACI.
6) Calculating the anomaly of ESI and ACI (ANO ESI and ANO ACI): The purpose of anomaly calculation is to reduce the anomalies in each data. The method entailed subtracting the value of ESI and ACI by 0.5. The value of 0.5 is obtained from the median value of both indexes because the total value of each index (ESI and ACI) is 1. By subtracting 0.5 from the values of ESI and ACI, the values of ESI and ACI will have a range from −0.5 to +0.5, and then it determines the quadrant position (see Fig. 2 for details).
7) Categorizing the vulnerability level: The vulnerability level is categorized into 5 classes, namely not vulnerable, less vulnerable, rather vulnerable, vulnerable, and high

Table 1
The selected indicators of exposure and sensitivity index (ESI) and adaptive capacity index (ACI).

Aspect	Indicator & weight	Data & weight	Description	Explanation
Physical	Built-up arê (0.1)	The proportion of built-up area (0.1)	Land use is correlated with the susceptibility. The vulnerability increases when the land use is more solid or has the high proportion of built-up area (Li et al., 2016).	The totality of built-up area divided by the total area of *kelurahan* (urban village).
	Fish pond & rice field (0.1)	The proportion area of fish pond (0.05) The proportion area of rice field (0.05)	The fish ponds and rice fields are vulnerable to the climate change. It has more potential loss of valuable plants and natural resources.	The total of fish pond area divided by the total area. The total of rice field area divided by the total area.
Demographic	Vulnerable people (women, children and the elderly) (0.15)	The proportion of women (0.05) The proportion of children (0−4 years old) (0.05) The proportion of elderly (over64 years old) (0.05)	Women, children, and the elderly are grouped into vulnerable people due to their incapability to escape and survive when hazards occur (Rasch, 2015). A higher proportion of women, children, and the elderly means more susceptibility to the hazards or risks.	The number of women divided by the total population. The number of children (0−4 years old) divided by the total population. The number of elderly (over 64 years old) divided by the total population.
	Population density (0.25)	The number of population density (0.25)	Population density influences the damage that may occur when hazard events occur (Rasch, 2015). The more densely populated an area is, the higher it is susceptible to damages when hazards occur.	The population of village divided by the total area.
	Poor people (0.15)	The proportion of poor people (0.15)	A higher proportion of poor people implies higher susceptibility to impacts of hazards.	The number of people defined as poor based on city classification divided by the number of population.
Economic	Livelihood (0.25)	The proportion of farmers (0.04) The proportion of fishermen (0.05) The proportion of people who work in trading sectors (0.02) The proportion of people who work in industrial sectors (0.02) The proportion of people who work in transportation sector (0.03) The proportion of civil servants (0.02) The proportion of retirees (0.02) The proportion of people who work in mine and energy sector (0.02) The proportion of people who work in service sectors (0.03)	The types of livelihoods have a relationship to available natural resources and climate conditions. Fishermen and farmers are more vulnerable to climate stimuli.	The number of farmers divided by the productive population (15−64 years). The number of fishermen divided by the productive population. The number of people who work in trading sector divided by the productive population. The number of people who work in the industrial sector divided by the productive population. The number of people who work in transportation sector divided by the productive population. The number of civil servants divided by the productive population. The number of retirees divided by the productive population. The number of people who work in mine and energy sector divided by the productive population. The number of people who work in service sector divided by the productive population.
Social	House type (0.255)	The proportion of permanent housing (0.255)	The quality of wall of dwelling units determines whether housing is susceptible to damages due to the hazards (Rasch, 2015). The housing with permanent walls (made from bricks and plaster) are more resistant to the impact of hazards.	The number of permanent houses divided by the total number of houses
	Educational level (0.14)	The highest level of family education • Elementary school (0.02) • Junior high school (0.03) • Senior high school (0.04) • College (0.05)	The level of education relates to the knowledge and capability to rebuild and recover from hazards (Rasch, 2015). The higher the level of education, the higher the people have better knowledge of mitigation and capacity to recover from the hazards.	The educational levels consist of 4 levels, namely: elementary school, junior high school, senior high school, and college. The educational level is determined by the majority of educational level attained by a family in a village with the following scoring methods:

Table 1 (*continued*)

Aspect	Indicator & weight	Data & weight	Description	Explanation
				(1) Elementary school (2) Junior high school (3) Senior high school (4) College
Infrastructures and facilities	Clean water source (0.15)	Whether (or not) the housing is serviced with clean water • Served by clean water service (0.1) • Not served by clean water service (0.05)	The condition of water and sanitation determine the vulnerability in housing without clean water service and proper sanitation—implying more probability of illness (Rasch, 2015). Housing with clean water service and private toilet is more adaptive to the hazards or risks.	The score as follows: (1) The village that does not have affordable clean water service (2) The village that has affordable clean water service
	Sanitation (0.06)	Type of latrine used (private toilet/public toilet/not using toilet) • Private toilet (0.03) • Public toilet (0.02) • Not using toilet (0.01)		The score as follows: (1) Not using toilet (2) Using public toilet (3) Using private toilet
	The number of education facilities (0.125)	Level of completeness of educational facilities in a village • Kindergarten (0.025) • Elementary school (0.025) • Junior high school (0.025) • Senior high school (0.025) • College (0.025)	The level of completeness considering the capacity and the accessibility of each type of educational and health facility. Complete services, where available, helps the people to cope and recover from the impact of hazards.	This study examined 5 types of educational facilities: kindergarten, elementary school, junior high school, senior high school, and college. A scoring method is applied here considering the capacity and availability of each facility. Where there is no such facility, the score is 0; and where such facility is available, the score is 1.
	The number of health facilities (0.27)	Level of completeness of health facilities in a village • Hospital (0.06) • Public health center (*puskesmas*) (0.05) • Sub-public health center (*puskesmas pembantu*) (0.045) • Doctor (0.04) • Polyclinic (0.03) • Midwife/birth center (0.025) • Neighborhood health center (*posyandu*) (0.02)		The 7 kinds of health facilities examined include: hospital, public health center (*puskesmas*), sub-public health center (*puskesmaspembantu*), doctor, polyclinic, midwife/birth center, and neighborhood health center (*posyandu*). A scoring method is applied here considering the capacity and availability of each health facilities for coping and reducing the impact of hazards. Where such facility does not exist the score is 0; and where it exists, the score is 1.

vulnerable. Table 2 shows the categorization levels of vulnerability based on ESI and ACI values. The categorization levels of vulnerability also converted into Quadrant models to explain the relative position of each area.

4. Results

4.1. Exposure and sensitivity index (ESI)

As described in Table 3, the ESI of Tegal and Lasem (small and medium cities respectively) are higher when compared to Semarang (big city). This means that Semarang is less sensitive to climate change hazards. Population density and livelihood have the highest weights and therefore, contribute more significantly to the final ESI compared to the other indicators. Semarang has relatively higher rate of population density in some of its fast-growing areas; and very low density in areas dominated by fish pond and mangrove plantation. There are also relatively fewer people in Semarang working in the primary sector and therefore, the city is not very sensitive in the economic aspect. Even Semarang has a higher number of younger and older people, as well as more built-up areas, its ESI is relatively low and does not contribute significantly to the final value of ESI.

Tegal and Lasem have same ESI values. Even though Tegal has a higher proportion of built-up areas, the city has less land-uses that are sensitive to climate (i.e. rice field and fish pond) compared to Lasem. There are slightly higher population densities and more poor people in Tegal (medium-sized city) when compared to Lasem (small city). However, there are more people working in the primary sector in Lasem when compared to Tegal. The variations in both cities have resulted in similar ESI values for the applied social and economic indicators.

4.2. Adaptive capacity index (ACI)

Tegal (medium city) has the highest value of ACI (Table 3). ACI represents the provided facilities including education, health, house type, and sanitation. By having the highest ACI values, Tegal is the city with better services compared to Semarang and Lasem. There are too many people (including

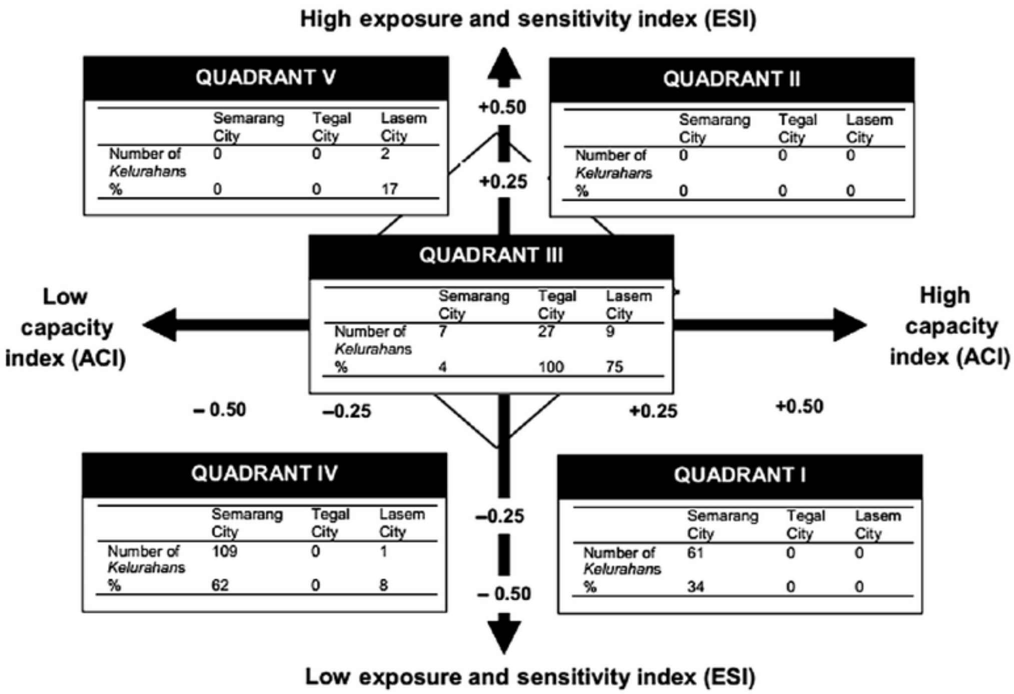

Fig. 2. The quadrant levels of vulnerability in Semarang, Tegal, and Lasem.

Table 2
The categorization levels of vulnerability (based on ESI and ACI anomalies).

Calculation results	Quadrant	Category
ESI<0, ACI>0, ESI − ACI<−0.25	1	Not vulnerable
ESI>0, ACI>0, ESI + ACI>0.25	2	Less vulnerable
ESI + ACI<0.25, ESI + ACI>−0.25, ESI − ACI<0.25, ESI−ACI>−0.25	3	Rather vulnerable
ESI<0, ACI<0, ESI + ACI<−0.25	4	Vulnerable
ESI>0, ACI<0, ESI − ACI>0.25	5	High vulnerable

Source: MCI (2017).

poor people) in the big city (Semarang). Most of them do not have access to sufficient basic services such as water, education, and health facilities. This makes the ACI of Semarang lower than Tegal. Nevertheless, Lasem (the smallest city in the study) has the lowest ACI value—indicating that the small city has limited capacity to provide adequate basic services to its people.

The position of each *kelurahan* according to ESI and ACI is shown in five quadrants (Fig. 2). *Kelurahans* in Quadrant V

Table 3
The comparative ESI and ACI values of Semarang, Tegal, and Lasem cities.

Point	Indicator	Semarang			Tegal			Lasem		
		Max	Min	Average	Max	Min	Average	Max	Min Value	Average
	ESI	**0.489**	**0.113**	**0.221**	**0.614**	**0.371**	**0.496**	**0.659**	**0.388**	**0.496**
A	Built-up area	0.100	0.002	0.061	0.100	0.010	0.058	0.100	0.005	0.039
B	Fish pond and rice field	0.051	0.000	0.007	0.051	0.000	0.021	0.058	0.012	0.039
C	Vulnerable people	0.138	0.041	0.067	0.138	0.116	0.125	0.139	0.114	0.125
D	Population density	0.250	0.001	0.027	0.250	0.012	0.134	0.250	0.027	0.110
E	Poor people	0.150	0.000	0.037	0.150	0.059	0.094	0.150	0.006	0.083
F	Livelihood	0.066	0.004	0.021	0.114	0.039	0.064	0.145	0.060	0.100
	ACI	**0.732**	**0.191**	**0.454**	**0.695**	**0.469**	**0.575**	**0.450**	**0.263**	**0.365**
G	House type	0.255	0.012	0.173	0.255	0.104	0.223	0.255	0.074	0.164
H	Educational level	0.050	0.005	0.014	0.030	0.005	0.009	0.005	0.005	0.005
I	Clean water source	0.100	0.000	0.052	0.100	0.100	0.100	0.100	0.000	0.025
J	Sanitation	0.030	0.000	0.030	0.030	0.030	0.030	0.030	0.010	0.028
K	The number of education facilities	0.125	0.025	0.085	0.125	0.025	0.074	0.100	0.025	0.060
L	The number of health facilities	0.240	0.020	0.101	0.240	0.085	0.138	0.135	0.045	0.082

has high level of ESI and low ACI. This means such *kelurahans* included in Quadrant V are highly exposed and sensitive due to the hazard events as well as has a low capacity index, thus, it is categorized as high vulnerable areas. In contrast, *kelurahans* in Quadrant I have low levels of ESI and high ACI values, indicating that the area is not vulnerable. Those *kelurahans* in Quadrant III have balanced values of ESI and ACI. The *kelurahans* in Quadrant II and IV have combinations of good ESI values and bad ACI values, and vice versa. As illustrated in Fig. 2, most *kelurahans* are placed in Quadrant III. Only *kelurahans* in Lasem have high vulnerable values in Quadrant I. There is no *kelurahan* in Quadrant II. *Kelurahans* in Semarang (big city) have various level of vulnerability, when compared to those in Quadrant III, IV, and V.

4.3. Levels of vulnerability assessment

Finally, Table 4 summarizes the level of vulnerability in the three selected cities. As the big city, Semarang has a combination of levels of vulnerability. Most *kelurahans* located along its main corridor (Fig. 3) of development are categorized as not vulnerable, while most others located in the downstream as well as in the upstream are vulnerable. This is in line with Yoo et al. (2014) for Jakarta (the biggest city in Indonesia with more than 10 million inhabitants) and Kumar et al. (2016) in Bangalore in India (also inhabited by 10 million people). These were done by considering physical and socio-economic aspects, resulting in variation of vulnerability levels. Areas that have experienced intensive hazards, high density and relatively significant number of poor people (in Yoo et al. (2014), poor people were represented by slum area) are likely to be classified as high vulnerable and vulnerable areas. On the other hand, areas with less density and better facilities and governance support (higher capacity) are likely to be less vulnerable. The case of Jakarta and Banglore showed significant similarity with Semarang where the least vulnerable areas are located in the commercial areas, with likely less settlement and better infrastructure support.

The level of vulnerability in the smaller cities is moderately comparable. All *kelurahans* in Tegal city are in quadrant III or categorized as “rather vulnerable”. Lasem, being the smallest city, has relatively the worst performance as the majority of its *kelurahans* are in quadrant III and few others (8% and 17% of its *kelurahans*) categorized as vulnerable and high vulnerable.

By combining the ESI and ACI, Tegal which represents a medium city with more or less 250,000 inhabitants has quite similar vulnerability levels among its *kelurahans*. Semarang (big city) has more combination of vulnerability level, indicating that the city has various sensitivity, exposure, as well as adaptive capacity in its *kelurahans*. However, further attention should be given to the small city as represented by Lasem. Due to its limitation of adaptation (mostly because of lack of public services) and high dependency on the primary sectors, all of its *kelurahans* are vulnerable.

As most of studies that have been connecting vulnerability and urbanization have focused on the macro level, and have put their concerns mainly on big cities (Birhanu et al., 2016; Kumar et al., 2016; Li et al., 2016; Qiu et al., 2015; Yoo et al., 2014), there are still lack of vulnerability comprehension on small and medium city size. Previous studies have clearly stated that urbanization does matter in regard to vulnerability level of a city and higher vulnerability would be experienced by big cities (more than one million inhabitants) due to their complexity. However, this study has shown an evidence that small city is also vulnerable not really because of the problems on its exposure and sensitivity, but rather because of its lack of adaptive capacity. Even though results from macro (provincial) level study, Qiu et al. (2015) has stated the needs to further elaborate various levels of analyses in connecting vulnerability and urbanization. Qiu et al. (2015) study demonstrates ecosystem vulnerability across provinces in China, and an influential variation on the vulnerability level mainly in the central provinces of China is related to the capacity. The study has also suggested in-depth study to have vulnerability assessment at multi-level scales to address the differentiation of vulnerability level in a more detail comprehension.

5. Discussion and implications

Due to climate change, every city faces one risk or another. Vulnerability assessment in city development presents a reliable process for identifying, categorizing, quantifying and ranking the vulnerabilities in cities, irrespective of their sizes. From the data presented in this study (and also taking into account earlier works that covered socio-economic aspects and supported infrastructures as main variables), there are at least two major determinant factors identified to be influential in the assessment results in the three selected cities.

5.1. Livelihood

Livelihood issues are the most important indicators that are commonly sensitive to climate change in the three cases analyzed. The metropolitan area (Semarang), being less

Table 4
The comparative levels of vulnerability of Semarang, Tegal, and Lasem.

Level of vulnerability	Semarang		Tegal		Lasem	
	Total of *Kelurahans*	Percentage (%)	Total of *Kelurahans*	Percentage (%)	Total of *Kelurahans*	Percentage (%)
Not vulnerable	61	34	0	0	0	0
Less vulnerable	0	0	0	0	0	0
Rather vulnerable	7	4	27	100	9	75
Vulnerable	109	62	0	0	1	8
High vulnerable	0	0	0	0	2	17

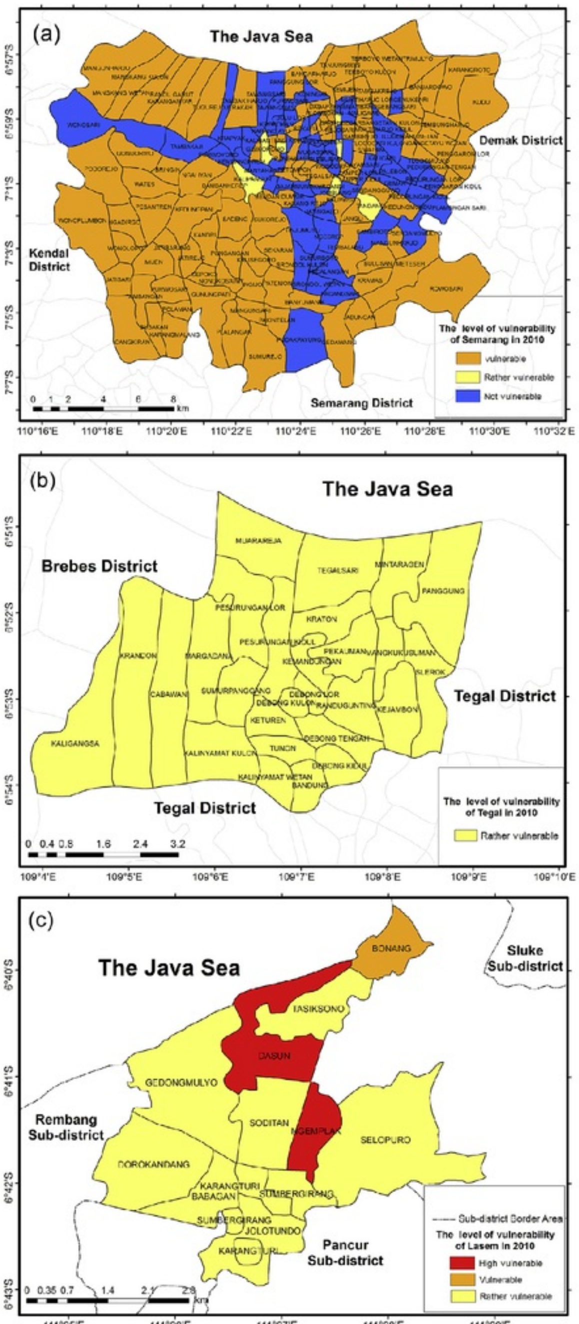

Fig. 3. Spatial vulnerability assessment mapping in (a) Semarang, (b) Tegal, and (c) Lasem.

dependent on primary sector, is less sensitive compared to the medium-sized city (i.e. Tegal) and the small-sized city (i.e. Lasem). Adger (2006) has argued that livelihood should be further elaborated as an important aspect in assessing vulnerability because it is directly related to food insecurity. Similarly, Handayani and Kumalasari (2015) also stated that livelihood is an important challenge to be addressed in order to balance the need of people who are working in primary sectors with the efforts in controlling environmental degradation.

From the perspective of literature, this study extends into the margins of Ferrol-Schulte et al. (2013) which dealt on coastal livelihood vulnerability in Indonesia, with focus on the decreasing productivity of fishery sector. In this regard, it has two key implications. Firstly, it has implications on food security in Indonesia. Since Indonesia is one of the biggest producers of fishery product worldwide, using the data from vulnerability assessment of coastal regions of the country to make policy decisions can help to reduce negative climate change impacts in the fishery sector. Secondly, the result of this study has urbanization and sustainability implications. It makes data available for understanding the consequences of intensive urbanization and its climate change relationships. Handayani and Kumalasari (2015) noted that the intensive urbanization is taking place in the coastal area of Central Java—the largest city in Indonesia—and called for the city dwellers to not only diversify, but to change their livelihood from fishery to other sectors. Furthermore, by combining the findings of Handayani and Kumalasari (2015) on the adaptive capacity of people in the area and the result of the vulnerability assessment in this study, it can be concluded (in terms of livelihood) that the area with high dependency on primary sectors (agriculture and fishery) is more sensitive to climate change even though they have good adaptive capacity—because adaptive capacity is not sufficient enough to fully reduce the level of their vulnerability.

5.2. *Urban form and urbanization*

Urban form appears as an important terminology when comparing the vulnerability assessment among the three selected cities. Generally, urban form refers to land use patterns influenced by activity and transportation system and settlement/population density (Jabareen, 2006; Handy, 1996). The findings of this study are in line with those found by Kumar (2016) and Yoo et al. (2014) because it indicates that population density and provision/distribution of public infrastructures/facilities matters in vulnerability level minimization. It is very important to ensure that the people and supported facilities are evenly distributed across the cities. It is very much related to the discourse of urban growth management, to ensure that the growth of the city is intensive enough but may still be able to provide sufficient environmental services. Jabareen (2006) believes that density is a critical determinant of a sustainable urban form. Maintaining population density (in combination with sufficient allocation for settlements), including urban infrastructures and green spaces contribute significantly to minimizing vulnerability levels. Therefore, mixed-use allocation should also be considered as an important factor in reducing vulnerability in prone areas.

This study may not have offered deep analyses on the influence of urban form or land use patterns on the vulnerability level, however, it has produced ideas necessary for connecting urban form (i.e. growth management) towards minimizing the vulnerability of cities. Nevertheless, as has been shown that (based on the indicators applied), a medium city (Tegal) performs slightly better than the bigger and the smaller cities because it does not have any *kelurahans* categorized as vulnerable or high vulnerable, this provides an answer to Way's (2016) question concerning how size matters in urban environmental management. It directly fills the gap in literature which Way (2016) noted concerning the lack of findings on the roles of small and medium-sized cities in urban environment. In the perspective of urbanization, this study (re) enforces the need for considering optimum sizes of cities when assessing vulnerability or risk in cities. It also shows that maintaining the size of urban populations is crucial for ensuring balance in environment conditions of cities, especially when a population is serviced with appropriate access to the public infrastructure.

6. Conclusion

There are numerous growing cities located in coastal areas across the globe. Most of them are prone to various types of hazards due to sea level rise, changing rainfall patterns, and rising temperatures as the result of climate change. Strategies for tackling urbanizations challenges in coastal areas demand for comprehensive understanding of how climate change may affect the future of these areas.

Vulnerability assessment methods provide opportunities for understanding how variables—such as socioeconomic and infrastructural variables in cities—play defining roles in urbanization and climate change relationships. While lack of data has limited vulnerability assessments to the macro level, this study has shown that it can be done at a micro level. The study determined different vulnerability levels of three dissimilar city sizes by analyzing their smallest possible units. Accordingly, the findings provide convincing evidence that enrich the discourse on livelihood diversity. It also addresses how the management of city sizes and growth allocations are crucial to maintaining the environment and socioeconomic balance of city inhabitants in general. Most importantly, it shows how to reduce vulnerability due to climate change impacts. The bigger the city, the more it is bound to have various levels of vulnerability among its sub-units or areas; and the more it's potential to have more vulnerable people. Thus, the study provides data necessary for making renewed efforts for addressing the impact of climate change on growing cities.

Acknowledgment

We would like to express our gratitude to University of Diponegoro and Ministry of Research, Technology, and Higher Education, grant number 022/SP2H/LT/DRPM/II/2016 for the funding for this research. We would also like to thank the government of Semarang, Tegal, and Lasem city (and their staff) for the data and shared information they provided during the survey period.

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