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Adaptation to coastal flooding and inundation: Mitigations and migration pattern in Semarang City, Indonesia

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ABSTRACT

As a global issue, climate change has been significantly influencing coastal areas and causing changes in marine and terrestrial environments. The increase in sea-level rise (SLR), for example, has worsened the quality of life of coastal communities, and this risk increases especially in coastal cities of the developing world. This paper aims to comprehend the variety of self-mitigations and the patterns of local migrations of communities in the northern part of Semarang City, Indonesia. The delineation of the risk areas for *Rob*, a local term for inundation and flooding caused by sea water overflow, was accomplished with the application of GIS. Interviews with the inhabitants were conducted to investigate the scale and frequency of *Rob* and the variety of mitigation, adaptation, and responses at the individual, household or community level. Further investigation was done to comprehend the reasons why people moved away from their current residence to their intended locations. The results show that most inhabitants prefer to stay and to adapt rather than to leave, due to social factors such as being comfortable with their community relationships. Those who wanted to move chose diverse locations spread across various areas of the city. Safer places in the hilly areas of southern Semarang and other residences close to their family or relatives were the most preferable. Based on this understanding, local government should encourage people to be more aware of the potential hydro-meteorological hazards threatening their environment.

1. Introduction

Influenced by marine and terrestrial environments, coastal areas are extremely vulnerable to climate change (Hansen, 2010), the impacts of which trigger sea-level rise (SLR). According to the Special Report on Emissions Scenarios of the Intergovernmental Panel on Climate Change (IPCC), the global mean sea-level is estimated to rise 22–34 cm between 1990 and the 2080s (McGranahan et al., 2007). SLR has caused coastal inundations in many locations around the world, causing many residents to live in discomfort. Its danger is usually measured by a set of parameters, such as the depth of water, duration, and velocity (Marfai and King, 2008a). This situation, in turn, induces major risks to coastal regions and the people. Approximately 600 million people and 2/3 of cities in the world are located in such areas (McGranahan et al., 2007).

About 23% of the world's population (around 1.2 billion people) live within 100 km of the coast and this figure is estimated to reach 50% in 2030 (Adger et al., 2012). This situation will increase the risk of the population affected by coastal inundation and other types of hydro-meteorological hazards, such as typhoons, hurricanes, sheet flooding, and coastal and river-based floods (Kötter, 2003).

In dealing with hydro-meteorological hazards, the communities make efforts to adapt in many ways, which may start with lower-effort measures then shift to higher-effort and more costly measures (Koerth et al., 2013a, b). When the hazards' pressure gets bigger, migration can be an option to overcome the problem (Black et al., 2011; Nawrotzki and DeWaard 2018). The decision to migrate can be influenced by the desire to earn economic opportunities, income recovery, climate amenities (Klaiber, 2014; Penning-Rowsell et al., 2013), and even personal history (Koerth et al., 2013a, b). The destination of migration is often considered by proximity to the workplace (Lu et al., 2018). For this reason, institutional mechanism and social network are essential to be regarded (Scheffran et al., 2012). The cases in South American countries, for examples, show that they have determined policies to address human mobility in the context of disasters and climate change

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(Yamamoto et al., 2017).

Located in tropical climate areas, Indonesia often faces extreme weather, including temperature and wind (Løvholt et al., 2014; Buchori and Tanjung, 2014; Buchori et al., 2018). Such climatic conditions, along with time, the growth in human activities, and environmental degradation, tend to become worse and lead to an increasing number and intensity of hydro-meteorological disasters. This country, covering about 88,000 km coastline and more than 17,500 islands, is highly vulnerable to the impacts of SLR (Sejati and Buchori, 2010; Maulana and Buchori, 2016; Marfai and King, 2008b; Marfai and King, 2007; Marfai et al., 2008a, b, c; Marfai et al., 2008; Firman et al., 2011; Marfai and King, 2008a; Buchori et al., 2018).

Semarang is a large developing coastal city in Indonesia, centred in the northern coastal and low-lying areas, and situated at an elevation of between five and ten metres above sea level. There are 20 villages in the coastal zone and its neighbour prone to coastal hazards (Marfai and King, 2008a). The rate of sedimentation along Semarang coast varies from 8 to 15 m per year, while the height of inundation in the coastal and low lying area reaches about 40–60 cm from the ground (Marfai and King, 2008a). This tendency leads to urbanisation and environmental problems, such as coastal erosion and sedimentation, over-exploitation of ground water resources, land subsidence, tidal inundation, and *Rob*, a local term for flood and inundation caused by sea water overflow. The term, *Rob*, is used because it is unique, in the sense that it mainly occurs in the northern coastal region of Java. Specifically, *Rob* refers to "inundation" that is mostly permanent and "flooding" that is temporary. Overall, this situation will increase the risk of flooding and other kinds of environmental damage in the coastal areas (Ardiansyah and Buchori, 2014; Susi et al., 2017; Buchori et al., 2013; Sejati and Buchori, 2010; Maulana and Buchori, 2016).

The *Rob* in Semarang significantly influences the community life (Marfai et al., 2008a, b, c; Buchori et al., 2018), and it has the potential to degrade many public activities. Previous studies have shown that the impacted people tend to adapt to the problem (Damen and Sutanta, 2003; Sejati and Buchori, 2010; Khadiyanto et al., 2017), with some of them tend to move to safer places elsewhere in the city.

Therefore, this study aims to observe various kinds of community adaptation, formed as structural and non-structural self-mitigations, and the willingness to move, including the locations and reasons for their decision. It is a continuation of the previous study of Buchori et al. (2018), revealing that the potential risks affected by hydro-meteorological hazards have improperly accommodated in the City Spatial Plan. The results of this study are expected to enrich our understanding in dealing with *Rob* and be beneficial for the local government to evaluate the City Spatial Plan, which has less concern on the issues of hydro-meteorological hazards. Moreover, the approach of this study can be replicated to other locations with comparable characteristics.

Following this introduction about the reasons why this study was essential, the next section is literature review on the previous studies about disaster mitigations and local migrations. Then, in the method section, how the data were gathered and analysed is explained. The next part is the analysis and discussion elaborating the fact findings and the knowledge from the observed literature. The final section concludes and gives the implications to the corresponding body of knowledge and recommendations to local government.

2. Disaster mitigations and local migrations

2.1. Disaster mitigations

The International Emergency Disaster Database (EM-DAT) defines a disaster as an event which enforces the local population to request external assistance at the national or international level, or whatever is acknowledged by multilateral agencies, or at least two sources, such as national, regional or international aid groups, and the media (Daramola et al., 2016). The ability to cope and recover from disasters with the minimum impact and damage is acknowledged as resilience (Cutter et al., 2008). The concept of resilience was first used by ecologists to illustrate the system's ability to assimilate change and disturbance, and retain critical functions within the particular domain (Holling, 1973). Regarding disaster, resilience is also recognised as the capacity of a community to withstand or adapt to a hazardous condition, and to establish acceptable functions and structures (Hung et al., 2016).

Resilience to disasters is vital for a community to enhance its ability to plan, absorb, and recover from adverse events in a timely and efficient manner. Lack of planning, land management and preparedness will increase the potential vulnerability of a community to a hazardous condition. Thus, taking decisive action by creating an effective disaster management system at the national and local levels is essential, particularly to produce a platform to ensure the community becomes resilient (Joerin et al., 2012; Cutter et al., 2014; Kötter, 2003).

As far as addressing a disaster is concerned, the community resilience should better start with mitigation, which relates to pre-activities that can eliminate or reduce the impact of the disaster (Montoya, 2003). Mitigation is used as a measure to predict, prevent, and respond to disasters (Keeney, 2004), and can affect the level of adaptation, although in the short term it has a small effect (Farber, 2007). However, it is crucial to suppress the impact of disaster losses, including from hydro-meteorological hazards.

One mitigation measure implemented before a disaster strikes is an early warning system, which can detect future disasters, provide information to people who are at risk, and review factors which endanger the decision-making and action process (Sorensen, 2000). Meanwhile, the form of mitigation performed while a disaster is in progress is an evacuation system. Evacuation will be effective if people and goods can be moved to safer areas within an acceptable timeframe (Chien and Korikanthimath 2007). However, effective evacuation is not easy, especially in developing countries that often face a lack of communication and public transportation. Nevertheless, it is still possible with sufficient preparation, not only by communities but also government institutions responsible for disaster management. A warning system and evacuation plan are therefore critical when dealing with a large-scale disaster, especially to prevent loss of life (Fuchs, 2010).

Mitigation strategies can be structural and non-structural (Saravanan, 2016; Thampapillai and Musgrave, 1985; Hunter, 2005; Poussin et al., 2012; Dawson et al., 2011; Kundzewicz, 2002; Marfai et al., 2008a, b, c; Kötter, 2003). Structural mitigation focuses on physical constructions to reduce or avoid possible hazard impacts. In cases of flood hazards, the traditional approach of structural flood mitigation relies on physical buildings like dams, dykes, and channel improvements (Kötter, 2003). Besides, it can also be formed as physical improvements or modifications of the building, such as elevating the house floor and building a second story house. Moreover, non-structural mitigation emphasises knowledge, public awareness raising, training, and education, along with practice or agreements, especially in policy and law (UNISDR, 2009). With flood hazards, non-structural measures include flood warnings, evacuation, floodplain land use management, flood checks, and flood insurance (Thampapillai and Musgrave, 1985). Although the two approaches are different, both types of mitigation have equally important roles, which may be best applied in combination (Johnston et al., 2014).

Coastal cities need particular attention related to community awareness and resilience towards hydro-meteorological hazards, especially in climate change cases. Adapting to climate change is, therefore, an essential part of ensuring that communities can live and work in the desirable places. Essential lessons outlined by several researchers on the climate adaptation in coastal area development are useful. They are able to improve our understanding on many aspects, such as its impacts (Parker, 2014; Hansen, 2010), risk and vulnerability assessment (Faustino and Sales, 2009; Gibbs, 2015; Johnston et al., 2014), management planning and sustainable adaptation (Hurlimann et al., 2014; Bi et al., 2013), and mitigation planning (Imaduddina and Subagyo,