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# Mapping Socio-Economic Vulnerability to Rob Flood Hazards in Coastal Cities, North Pekalongan District, Pekalongan City

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**Keywords**

North Pekalongan District; Urbanization of coastal areas; Vulnerability assessment.

**Abstract**

Climate change brings danger to several areas, especially in coastal urban areas. One of them is the tidal flood which experienced inundation. Tidal floods pose a serious threat to the sustainability of social life and economic growth. Assessment of social and economic vulnerabilities is needed to overcome the risk of disaster hazards due to climate change in the form of coastal tidal floods in cities. This research is expected to be able to describe socio-economic vulnerability through the variables of population density, age, gender, occupation, and level of education to tidal floods that have occurred in 42% of the area. The research method used is quantitative analysis, scoring, and geographic information system modeling with village analysis units. The results showed that Panjang Baru Village was the most vulnerable area because of the high density and low-income levels of the people, most of whom were fishermen and farmers households. It also indicates the contribution of population density, level of education, and employment to the level of vulnerability. This study states that the socio-economic aspect is an important factor that must be considered for the sustainability of life and community adaptation to the threat of climate change, especially tidal floods.

## 1. INTRODUCTION

Coastal areas have a strategic role in Indonesia. Several main cities on Java Island are located in coastal areas, namely Jakarta, Semarang, and Surabaya (Ward et al., 2010; Cahyadi et al., 2013). The World Bank (2014) explains that in 2025, 68% of the population will live in Indonesian cities and it is predicted that this will continue to increase to 82% of the population in 2045. The phenomenon of climate-related hazards has become an urban development *issue*. the most challenging at the moment. Climate change brings danger to several areas, especially in coastal urban areas. This climate problem is exacerbated by various other problems such as the environment and ecological systems that continue to deteriorate. Along with the phenomenon of climate change, these coastal cities are becoming increasingly prone to disasters (Cahyadi et al., 2013).

One of the disasters that occur in coastal areas is flooding or what is also called rob (Blackett and Hume, 2006). Tidal floods are caused by sea level rise and/or land subsidence resulting in inundation *(* Handayani, 2020). Tidal floods can occur when the tide is in a position higher than the ground level which is then accompanied by a high volume of river flow from upstream (Harley, 2013). Climate change, in relation to coastal urban areas, has been shown to contribute to the socio-economic vulnerability of communities along with an increase in coastal urban populations (Kumar et al., 2010).

The phenomenon of climate change which has an impact on the dangers of tidal flooding has affected urban coastal areas with a higher risk when compared to non-urban coastal areas (Kumar et al., 2010). The danger of tidal flooding is also exacerbated by conditions of intensive subsidence in urban coastal areas due to the high intensity of development of built-up areas in urban coastal areas (Harley, 2013). Along with the phenomenon of climate change, these coastal cities in Indonesia are receiving quite serious threats to disaster hazards,

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especially tidal floods (Cahyadi et al., 2013). The threat of flood disasters in urban coastal areas is serious because it has an impact on physical, social, economic, and environmental damage (Blackett and Hume, 2006). The impact of floods poses a serious threat to the sustainability of social life and economic growth in urban coastal areas (McGranahan et al., 2007).

Assessment of social and economic vulnerability is needed to overcome the risk of disaster hazards due to climate change in the form of tidal floods in coastal cities (Kumar et al., 2016). The phenomenon of urbanization will have an impact on increasing levels of social and economic vulnerability (Cutter et al, 2000). High socioeconomic vulnerability can occur if an area is dominated by high, low-income residents. In addition, socioeconomic vulnerability itself can be described as a benchmark related to the *socioeconomic characteristics* of the community in the process of facing and recovering from a disaster, so vulnerability will be a sign of socioeconomic conditions that can affect regional losses due to disasters caused by climate change. (Wang & Shaw, 2018).

Based on Presidential Decree Number 48 of 2014, the Pekalongan area is part of the *North Java Super Corridor as a center of economic growth, especially in the industrial sector (Hudalah et al, 2020).* North Pekalongan District in Pekalongan City is included in the northern coastal area which experienced tidal flooding. According to Cahyadi et al. (2013), the average flood height is 50 cm covering an area within 4 km of the Pekalongan coastline. Meanwhile, land subsidence ranges from 4.8 to 10.8 cm/year (BPBD Pekalongan, 2021). Based on data from the Central Java Pusdataru Service which was strengthened by Cahyono (2022), in 2020, it is known that the area of flood inundation in North Pekalongan will reach 618 hectares or the equivalent of 42% of the area of North Pekalongan. The population growth of North Pekalongan in the 2010-2022 period reached 10.44% from 73,159 people to 80,799 people (North Pekalongan in Figures 2010 and 2022). The city of Pekalongan is the center of the batik industry, especially in North Pekalongan District. In 2022, the number of batik craft industries is 161 units with a workforce absorption of 483 workers. Therefore, Pekalongan Utara District makes an important contribution to the growth of the creative economy due to the development of creative industries. This condition exacerbates the high intensity of urban activity and dense population which makes the environment worse. So, it is estimated that the number of areas that are socially and economically vulnerable to tidal flooding will continue to increase.

Table 1. Previous Research on the Vulnerability of Coastal Areas

| Author, year Title | Research result | Research Methods and Differences |
|---|---|---|
| Flanagan, BE et al. 2011. *A Social Vulnerability Index for Disaster Management, Journal of Homeland Security and Emergency Management* | Social vulnerability refers to socio-economic and demographic factors that affect community resilience. This research shows that in a disaster context, socially vulnerable communities are more likely to be adversely affected, where they tend not to recover and find it difficult to adapt. Addressing social vulnerabilities effectively can help reduce human suffering and economic losses after a disaster. The location of this research is in the New Orleans area, which is the coastal area of the United States state of Louisiana. This study describes the development of a social vulnerability index from several variables including poverty, employment, income, education level, age, disability group, single *parenting*, ethnicity, housing structure, access to transportation, and population density. | • Quantitative approach through scoring from the percentile ranking using the components of the SVI index<br>• In the previous research, the focus was on finding the potential value of the impact of the hurricane disaster to know which variables have the greatest influence on social vulnerability, while in this study it examines the spatial distribution of the level of socio-economic vulnerability.<br>• The previous research scale covered 1 city of New Orleans. Meanwhile, in this study, the focus was on the scale of the North Pekalongan sub-district. |

| | | |
|---|---|---|
| Tate, E., 2012. *Social vulnerability indices: a comparative assessment using uncertainty and sensitivity analysis* | This study focuses on the evaluation and comparison between social vulnerability indices through uncertainty and sensitivity analysis. The social vulnerability index is a tool used to assess the vulnerability of a community or population to various hazards or stresses by combining several social, economic, and demographic indicators to measure the vulnerability of a particular population. The findings of this study are that different social vulnerability indices can produce varying results (variability value index), changes in the weights and parameters assigned to the factors in the index can lead to different vulnerability ratings (sensitivity index), and special considerations of the study context emphasize that social vulnerability is context-specific and that a one-size-fits-all approach may not be appropriate. | The focus of this research is to compare and validate the analysis of uncertainty and sensitivity in social vulnerability to all natural disaster hazards through a quantitative approach using deductive, hierarchical, and inductive methods in solving them. Meanwhile, in this study, the assessment focuses on assessing the level of vulnerability and spatial distribution of tidal floods |
| Rufat, S., Tate, E., Burton, CG, & Maroof, AS 2015. *Social vulnerability to floods: Review of case studies and implications for measurement* | *massive* research aims to examine the concept of social vulnerability in the context of flooding in 67 cases during the 1997-2013 period worldwide. Social vulnerability refers to the vulnerability of individuals, communities or society to the adverse effects of flood hazards. Social, economic, and demographic characteristics, as well as institutional and governance aspects, are used in this study. The complexity of social vulnerability and the factors that contribute to different impacts on vulnerable communities (populations). There are challenges and limitations associated with measuring social vulnerability to flooding such as the dynamic nature of vulnerability, qualitative barriers, spatial and temporal variability of vulnerability, and the need for reliable and comprehensive data. | • The method used in previous research is content analysis with a qualitative approach which assesses the perspectives of several articles related to the most influential components from each country.<br>• This study focuses on identifying the main causes of social vulnerability to the effects of flooding, while this research does not only discuss the contribution of the socio-economic component but also identifies the spatial distribution of socio-economic vulnerability to the effects of tidal flooding in the Besir area.<br>• The scale of previous research includes a global scale. |
| Kumar, P., Geneletti, D., Nagendra, H., 2016. *Spatial assessment of climate change vulnerability at city scale: a study in Bangalore, India* | This research in Metropolitan Bangalore aims to analyze and assess a comprehensive vulnerability to climate change at a city scale. This study adopts a spatial assessment approach and integrates multiple factors to evaluate vulnerability. This study shows that policymakers and urban planners can draw lessons from developing strategies that are effective in the context of climate change adaptation in Bangalore. Researchers considered many factors that contribute to vulnerability, such as socio-economic characteristics, land use patterns, and environmental conditions. | • The method used is quantitative analysis through weighting and spatial multicriteria evaluation<br>• The scale in this study includes the city scale.<br>• In previous research, the focus was on assessing vulnerability evaluation from social and environmental aspects as well as adaptation based on the impacts of climate change. Whereas in this study the focus of research is not only on climate change but vulnerability to tidal floods. |

| | | |
|---|---|---|
| Handayani et al, 2017, *Vulnerability assessment: A comparison of three different city sizes in the coastal area area of Central Java, Indonesia* | Vulnerability assessment is a method that provides an opportunity to understand variables such as socioeconomic and infrastructure variables in playing a role in the discourse on the relationship between urbanization and climate change. Vulnerability assessment can be carried out on a micro-scale. Comparative research on cities of different sizes shows that the larger the city, the more it has various levels of vulnerability among its smaller regional units (sub-units). | • The method used is scoring, and weighting through the city-level FGD results.<br>• In previous research based on the type of city, where the research scale focused on three coastal cities, while in this study the research focus was on the sub-district scale<br>• In previous studies, research focused on vulnerability to climate change in coastal areas, while this study involved a focus on vulnerability to tidal floods. |
| Faniza, V, Pradoto, W 2019, *Socio-ecological vulnerability assessment and the results in spatial patterns: a case study of Semarang City* | This research is aimed at examining socio-ecological vulnerability and the resulting spatial pattern on a city scale. Variables such as population density, education level, livelihood, income, and dependency ratio are needed to assess socio-economic aspects. In addition, in terms of environmental variables such as land use, topography, geology and climatology. This study analyzes the relationship between the vulnerability-resilience of socio-ecological systems and land cover patterns. Based on the case study, the findings show that almost 28% of the Semarang city area is socially-ecologically vulnerable. The characteristics of coastal cities provide results where the high vulnerability areas are located in the northern coastal area of Semarang City. | • The method used is descriptive quantitative using scoring and spatial analysis<br>• In previous research, it examined social and environmental resilience by involving land use, slope, and climatology variables. while in this study the focus is on the vulnerability variables from social and economic aspects.<br>• The scale in the previous study was the city of Semarang, while in this study the focus was on the district scale |
| Haryanti, V, G, & Yuliastuti, N. 2021. *Identification of the coastal inundation disaster and its effect on social vulnerability in north Semarang district, Semarang city* | This research was conducted in North Semarang District. The variables used in this study were gender, education, income, special needs, vulnerable age and population density. high susceptibility value. high vulnerability is caused by the low role of women, educational conditions, income, and lack of inclusiveness for evacuation facilities for groups with disabilities. | • The method used is a descriptive quantitative scoring technique and standardized z-score with data collection techniques through questionnaires<br>• In the previous study, the object studied was 99 groups of families living on the coast of Semarang City, while in this study the object of research was the condition of the entire community which was described through the interpretation of census data in the coastal area of Pekalongan Utara District. |

Previous research on socio-economic vulnerability usually discusses vulnerability at a macro scale and is associated with community adaptation to disasters/threats. Flanagan (2011) for example examines vulnerability in New Orleans which illustrates social vulnerability if managed effectively can help in social losses and economic losses for the community. Research by Kumar et al. (2016) in Bangalore shows that the description of socio-economic vulnerability conditions is one of the important considerations in formulating policies to create community resilience to the threat of disaster hazards due to the phenomenon of climate change. Faniza and Padoto (2019) conducted an environmental assessment and disaster risk assessment in Semarang which showed the socio-ecological level of community vulnerability. Handayani et al. (2020) argue

that the process of mapping the level of vulnerability is an important tool in describing scenarios of spatial distribution in the local context which has been studied comparatively in Tegal City, Semarang City, and Lasem City. Based on the studies of researchers, it can be said that there are groups of people who tend to be vulnerable to the threat of disaster hazards. This is caused by the community's inability to deal with and recover from the hazards of the disaster (Adger et al., 2007, Cutter et al, 2000, Zhou et al., 2012).

This social-economic vulnerability mapping research in North Pekalongan departs from the assumption that creating community resilience to disasters is not entirely determined by physical intervention in the form of disaster management infrastructure development but can also be determined by the process of assessing the level of community vulnerability to disasters, especially those that are influenced by socio-economic conditions. Vulnerability caused by changes in socio-economic characteristics is a factor that determines the level of community adaptability to disasters (Sen, 1987). Pekalongan Utara District was chosen as the study area considering its status as one of the most vulnerable areas on the North Coast of Central Java. The city of Pekalongan has been hit by tidal floods since 2010 (Prihanto, 2012, Cahyono and Nugroho, 2022). This research will provide an overview regarding the level of socio-economic vulnerability of people in urban coastal areas that have not been widely discussed at the smallest delineation with the most possible data to obtain. This research will update research by Buchori (2015) regarding a vulnerability in the Pekalongan coast. This research departs from the question "How is the distribution of social and economic vulnerability levels in North Pekalongan District?"**.** The purpose of this study is to map the level of socio-economic vulnerability through assessment and spatial distribution. This research wants to understand how the relatively even distribution of urban coastal areas can experience different levels of vulnerability. This research was conducted by identifying and spatial analysis related to the socio-economic vulnerability of the community in the coastal area of Pekalongan City. This research is expected to provide benefits for Pekalongan City development planning, especially in terms of disaster risk management through a socio-economic approach, so that urban development is carried out in a balanced way with improving the quality of society.

Table 2. Justification of Indicators for Socioeconomic Vulnerability Variables

| *Research variable* | *Explanation* | *Indicator* | *Theory source* |
|---|---|---|---|
| Population density | High population concentration or population density in an area makes it difficult to evacuate from tidal floods | ● Total population;<br>● Village area;<br>● Built-up Area;<br>● Population Density Level. | Johnson Jr and Zeigler, 1986; McMaster, 1988; McMaster, 1988 |
| Age | The elderly and children are an age group that is very vulnerable to changes in conditions, in this case, tidal floods due to climate change | ● Number of Population Under 14 Years of Age;<br>● Number of Population Aged Over 65 Years. | McMaster, 1988; O'Brien and Mileti, 199; Flanagan et al., 2011 |
| | Children (<14 years) and the elderly (>65 years) have a high dependence on the help of others in dealing with exposure to the dangers of tidal floods | | Cutter et al., 2000; Cutter et al., 2003 |
| Gender | Women tend to have limited ability and physical strength in saving themselves compared to men | ● Number of women<br>● Number of men<br>● *Sex ratio* | Rufat et al., 2015; Morrow, 1999 |
| | The recovery ability of the female sex tends to be more difficult than that of the male. *Specific sectoral* tendencies in terms of employment make it difficult for women to adapt to new situations | | Cutter et al., 2003 |

| | | | |
|---|---|---|---|
| Livelihood | The livelihood variable is considered to represent economic vulnerability. Jobs in the agricultural and fisheries sectors tend to have a more influential impact on changing conditions, especially the hazard of tidal floods | ● Number of residents with livelihoods as farmers;<br>● Number of residents with livelihoods as fishermen;<br>● Number of residents with livelihoods as farmers;<br>● The proportion of the total population livelihood fishermen at productive age. | Cutter et al., 2003 |
| Level of education | Communities with higher education levels tend to have access to disaster-related information | ● The number of the population graduated from elementary school<br>● Total Population Middle School Graduates<br>● Number of Population High School Graduates<br>● Number of College Graduates | Cutter et al., 2003, Holland, 2011 |
| | Regions with a high education level representation tend to influence access to decent jobs, resources, and income to assist in the recovery process. | | Fatemi et al., 2017 |
| Poor Residents | Low-income people or groups of poor people are one of the representatives of the economic vulnerability of an area due to limited resources and difficulties in recovering from the dangers of floods. | ● Number of poor people<br>● Number of poor families<br>● Number of pre-prosperous families | Dasgupta, 1995; Cutter et al., 2000 |

### 1.1 Disaster, Hazard, and Vulnerability Concept

The paradigms of the concept of disaster *(disaster),* hazard *(hazards),* and vulnerability *(vulnerability)* are often related to the paradigm of disaster mitigation in the framework of disaster management (Wibowo, 2010). Disaster can be interpreted as an event or series of events that threaten and disrupt people*'s* lives and livelihoods caused by natural factors and non-natural factors. In addition, human factors can also cause disasters, which can cause casualties, psychological impacts, property losses, and environmental damage (BNPB, 2013). Hazards *are* natural and man-made phenomena that have the potential to threaten human life, property loss, and natural damage (Wibowo, 2010).

Meanwhile, the IPCC (2007) defines vulnerability *as* a level in a system where the system is unable to deal with adverse impacts and is easily disrupted by global climate change, such as climate variability and extreme climates. The function of the system can also be seen from its sensitivity and adaptive capacity to global climate change. According to Wibowo (2010), vulnerability can be interpreted as a condition of a particular community that leads to or causes an inability to face the threat of danger. So vulnerability can be something that needs to be known before a disaster occurs because it relates to potential threats. Social vulnerability denotes social conditions concerning fragile resilience in the face of danger. The fragile social condition in a disaster situation can cause huge losses. While economic vulnerability shows the condition of the level of fragility of the economy is facing the threat of danger. At this stage, the economic conditions and social dynamics of the region will determine the level of community resilience in facing the challenges of climate change. The relationship between disaster, hazard, and vulnerability can be described as mutually exclusive. Vulnerable (fragile) socio-economic conditions will find it difficult to deal with disasters, even the threat of danger. Strong socio-economic conditions will reduce negative impacts due to hazards that occur in the social and economic context.

### 1.2 The threat of Rob Flood Hazards in Coastal Areas

Sea *level rise* due to global warming is one of the problems faced by coastal or island countries in the world (Kobayashi, 2003). Sea level rise in the world in 2010 will increase by around 18 cm to 59 cm (IPCC, 2007). Then sea level rise will range from 0.21 cm/year to 0.68 cm/year, or an average of around 0.44 cm/year. This

phenomenon causes flooding in coastal areas (rob) which in the future has the potential to get bigger. The many phenomena of coastal flooding or what is commonly called tidal flood inundation, in the northern coastal area of Java Island at this time, is probably one result of changes in sea level due to global warming (Marfai, 2011). Global warming has a broad and serious impact on the bio-geophysical environment, such as sea level rise, increased rainfall, and floods, climate change, extinction of certain flora and fauna, migration of fauna and pests, and so on (IPCC, 2007).

Research on disaster focuses on influencing variables which include hazard or threat, vulnerability or sensitivity, and adaptability. Vulnerability is the tendency of a system to experience negative impacts which includes sensitivity to negative impacts and lack of adaptive capacity to deal with negative impacts. The vulnerability of a system to climate change is a function of its exposure, sensitivity, *and* adaptive capacity (IPCC, 2007). Cutter (1996) states that vulnerability is a basic concept of hazard mitigation. Hazard studies should start with a vulnerability assessment. Socio-economic vulnerability must be a central issue to research because of the causal effect of the level of vulnerability and the socio-economic characteristics of society, especially for many developing countries where coastal areas are usually the most densely populated areas and concentrations of poverty and which create more complex disaster mitigation problems. The impact of disasters on the continuity of social and economic activities of the community, such as disruption of the function of coastal areas and coastal cities, disruption of the function of urban infrastructure, disruption of the environment for settlement activities, reduced productivity of agricultural land to an increased risk of disease outbreaks (Klein et al., 2003). Vulnerability can be observed from several basic things, namely poverty, resources, ideology, economic system, dynamic pressure (local institutions, investment, local markets, macro forces, education, environmental degradation, training, soft skills, freedom of the press, population expansion, and urbanization), and physical environmental conditions: Hazardous locations, infrastructure and buildings, risky living, local economy, low-income levels, and public action (Winser et al, 2004).

## 2. METHOD

### 2.1 Description of Research Locations

Pekalongan City is one of the vulnerable cities on the north coast of Central Java. The most vulnerable area is Pekalongan Utara District, which consists of seven sub-districts (villages), namely: Bandengan Sub-District, Degayu Sub-District, Krapyak Sub-District, Kandang Panjang Sub-District, Padukuhan Kraton Sub-District, Long Baru Sub-District, Long Wetan Sub-District. The Pekalongan City BPBD stated that the area of the kelurahan which is prone to exposure to tidal floods is 1,057 hectares or around 23.36% of the total area. Tidal floods that were quite severe occurred from May to June 2022. The tidal floods inundated several areas in North, West and East Pekalongan Districts. Based on the results of online interviews with the Pekalongan City Public Works Office, in 2021 it is known that the pattern of distribution of inundation areas affected by tidal floods has changed after the construction of flood control infrastructure in the form of a 2-meter-high embankment that stretches from the Kandang Panjang sub-district to the Bandengan sub-district. In general, areas affected by tidal floods have tidal water levels reaching 30 cm to 80 cm with an average inundation period of 2 weeks. Based on the Pekalongan City BPBD disaster report document (2021) regarding the data for recording flood victims, it is known that 755 residents were victims of the flood incident in Pekalongan City.

The population of North Pekalongan District is 80,779 people with a population density of 5430 people/km2. The population is dominated by male residents. Krapyak Village is the most populated area with a population of 18,490 people or 23% of the total population, while Bandengan Village has the least population with a population of 6158 people or 8% of the total population. In the context of education level, the population of North Pekalongan District is dominated by high school graduates. Based on statistical data for 2022, the sub-districts with the highest number of sub-district households are Krapyak Village with 3,698 households, and Kandang Panjang Village with 1,232 households.

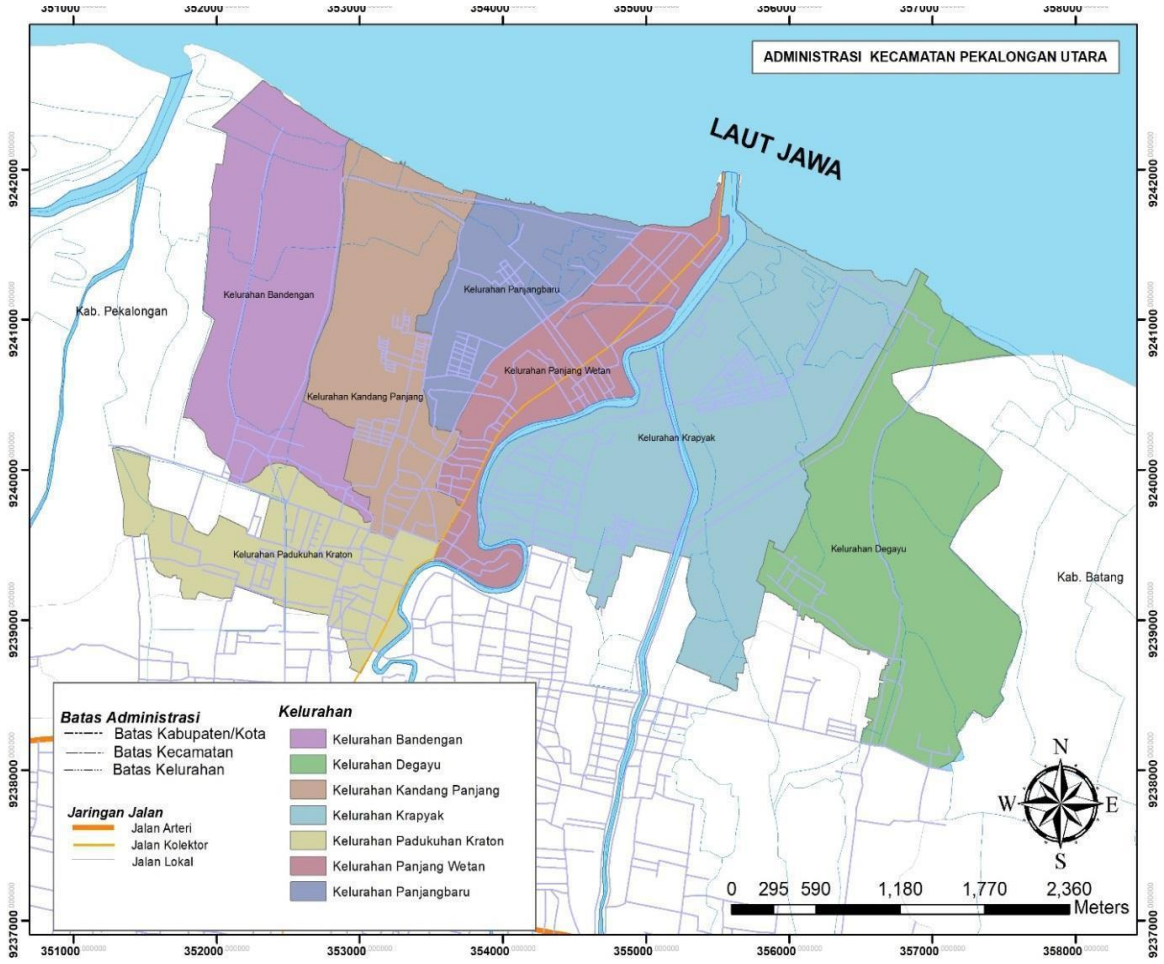



Figure 1. North Pekalongan District, Pekalongan, Central Java.

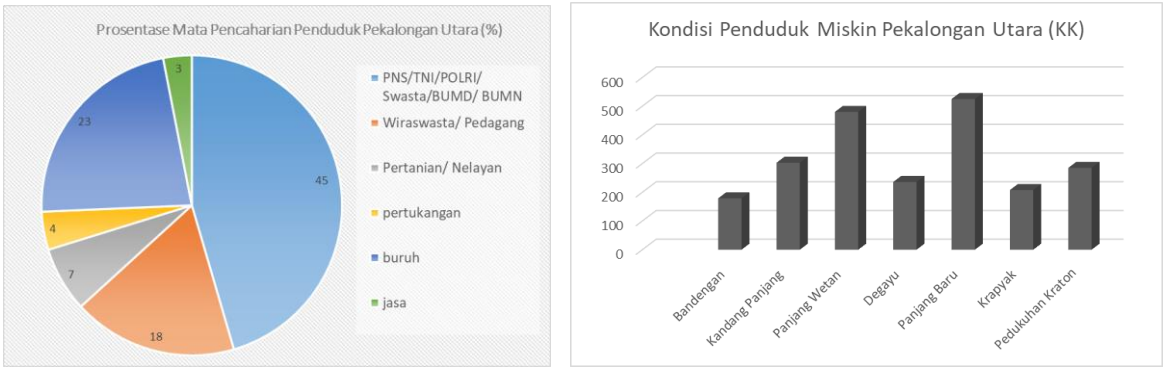



Figure 2. Livelihood Conditions and Poor Population in North Pekalongan District.

## 2.2 Statistical analysis

In this study, the method used is descriptive quantitative. The quantitative approach itself is an approach used by experts to collect, analyze and interpret data in the form of numbers (Creswell, 2009). Quantitative analysis in this study is used as an assessment technique that involves the process of calculating *the scoring* of each socio-economic vulnerability indicator. The scoring method is very important because it can represent the importance of each of the indicators applied. scoring itself is the most common calculation approach in measuring the level of vulnerability, especially in social contexts (Tate, 2012). Geographic information system (GIS) modeling based on indicators of socio-economic vulnerability can represent real conditions in the field. The collaboration of these two methods is an advantage in this research because the research results presented can be visualized in the form of a spatial distribution. Therefore, through quantitative analysis methods and

GIS modeling, it can be seen the spatial distribution related to socio-economic vulnerability based on predetermined variables. The data obtained from secondary sources comes from the government census documents of Pekalongan City. The level of socioeconomic vulnerability is assessed through the following steps, including:

1. Identifying and establishing indicators based on socio-economic vulnerability data: Socio-economic vulnerability indicators and data were obtained based on a literature review and then adjusted according to data availability and regional characteristics.
2. Calculating socio-economic vulnerability data: this data calculation stage aims to get the actual value of the data used. The calculation process is carried out using two methods, namely the ratio method and the scoring method. The ratio method requires dividing the value of each data with other matching data. For example, population density is the ratio between the total population of a sub-district and the area of the area. The scoring method is used for indicators which include indicators of population density, age, gender, livelihood, level of education, and poverty. Details of the method used for each data can be seen in Table 4.
3. Interpretation of spatial distribution patterns of vulnerability conditions based on variables using a geographic information system approach called GIS. The approach is carried out by combining the results of statistical analysis calculations into ArcMap to obtain the results of the distribution of spatial patterns of social and economic vulnerability in the Pekalongan Utara District.

### 2.3 Research variable

The research variables were obtained from the results of a literature review of several studies related to social and economic vulnerability. The results of the synthesis of the literature are represented in the elaboration of the synthesis of variables and indicators of social and economic vulnerability (Table 3.).

Table 3. Synthesis of Socio-economic Vulnerability Variables to theory according to Experts

| *Socioeconomic Vulnerability Index Variable* | *Source* | | | | | | | *Research variable* |
|---|---|---|---|---|---|---|---|---|
| | *Flanagan et al., 2011* | *Cutters 1995; 2000; 2003* | *Kumar et al., 2016* | *Birkman & Wiesner 2006* | *Wang & Shaw, 2018* | *Fatemi et al., 2017* | *Rufat et al., 2015* | |
| Gender | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 1. Population Density<br>2. Gender/Gender<br>3. Age<br>4. Level of Education<br>5. Livelihoods/Job<br>6. Poor People |
| Age | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Household composition/household structure | ✓ | ✓ | | | | ✓ | | |
| Population density | ✓ | ✓ | | | ✓ | | ✓ | |
| special needs | | ✓ | | ✓ | ✓ | | | |
| Dependency ratio | | ✓ | | ✓ | | ✓ | | |
| Education | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | |
| Livelihoods /Income | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| Race/ethnicity and minorities | ✓ | ✓ | | | | | | |

| *Socioeconomic Vulnerability Index Variable* | *Source* | | | | | | | *Research variable* |
|---|---|---|---|---|---|---|---|---|
| | *Flanagan et al., 2011* | *Cutters 1995; 2000; 2003* | *Kumar et al., 2016* | *Birkman & Wiesner 2006* | *Wang & Shaw, 2018* | *Fatemi et al., 2017* | *Rufat et al., 2015* | |
| Housing area | ✓ | | | | | | | |
| Transportation | ✓ | | | | | | | |
| Poor Residents | | ✓ | ✓ | | ✓ | ✓ | ✓ | |

Adjustment of socio-economic vulnerability variables is adjusted to the availability of data and the study area in Pekalongan Utara District. This study uses 6 (six) main variables in measuring the level of socio-economic vulnerability in North Pekalongan District. The following is an explanation regarding the justification of research variables and their operational definitions:

1. Population density

Population distribution and density can be indicators of vulnerability. This indicates that a higher population concentration in an area reflects the density of the area, causing challenges and difficulties for residents in the evacuation process in the event of exposure to hazards (Johnson Jr and Zeigler, 1986; McMaster, 1988; Cova and Church, 1997).

2. Children and Seniors (Age)

Based on age, children and the elderly are vulnerable age groups. The condition of the vulnerable age group can be described by the condition of the unproductive age group, namely children (<15 years) and the elderly (>65 years). Children and the elderly in particular have difficulty moving and are more likely to have medical problems as a result of certain hazard exposure situations. (McMaster, 1988; O'Brien and Mileti, 1992; Flanagan et al., 2011).

3. Sex Ratio (Gender)

Gender can also be one of the more vulnerable social indicators of the population. sex comparisons indicate a vulnerable condition due to lack of access to resources and differential exposure (Liverman, 1990; Cutter, 1995; Fothergill, 1996; Enarson and Morrow, 1998). In particular, the female sex has a higher vulnerability than the male, this is due to their physiological and social disadvantages. (Morrow, 1999; Cutter, Boruff and Shirley, 2003).

4. Livelihood

Economic status determines a household's financial capacity to be able to bear losses resulting from exposure to hazards (Cutter, Boruff and Shirley, 2003; Hajra et al., 2017). Farmers and fishermen who work in the agricultural, fishery, mining and forestry sectors are considered as the main variables in viewing the condition of the vulnerability of types of livelihoods that are related to available natural resources. climate conditions will affect livelihoods that depend on natural conditions, as fishermen and farmers are more vulnerable to climate change.

5. Level of education

The level of education reflects a person's knowledge and skills and can significantly affect individual capabilities in reducing one's level of social vulnerability (Cutter, Boruff and Shirley, 2003; Holland, Lujala and Rod, 2011). The level of education consists of three levels, namely elementary, junior high and high school. The level of education is largely determined by the level of educational graduates attained by residents in a Kelurahan.

6. Number of poor people

The poor are more vulnerable to certain hazards due to a lack of resources, poor housing quality, and an inability to recover quickly (Burton, Kates and White, 1993; Dasgupta, 1995). Wealthy households may experience greater material losses during hazard events, but such wealth allows them to be able to cope with large losses through insurance, social safety nets, and rights, and thus, recover more quickly from the effects of hazards (Cutter, Mitchell and Scott, 2000).

Table 4. Variables and Socioeconomic Vulnerability Scoring

| No | Variable | Scoring | | | Explanation |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | |
| 1 | Population density | Population Density 2,303 – 4,869 people/km $^2$ | Population Density 4,870 – 7,435 people/km $^2$ | Population Density 7,436 – 10,001 people/km $^2$ | The population of the kelurahan is divided by the total area in km $^2$ |
| 2 | Children and elderly (age) | Non-productive age ratio 0.265 – 0.287 | Non-productive age ratio 0.288 – 0.310 | Non-productive age ratio 0.311 – 0.332 | Total ratio of non-productive age (children and the elderly) to the total population. |
| 3 | Sex Ratio (gender) | The ratio of the number of males and females >100 | The ratio of the number of men and women = 100 | The ratio of the number of males and females <100 | Population ratio of the number of males and females (Males per 100 Females) |
| 4 | Livelihood | Proportion of farmers and fishermen in productive age 0.005 – 0.049 | The proportion of farmers and fishermen in productive age is 0.500 – 0.093 | The proportion of farmers and fishermen in productive age is 0.094 – 0.139 | the ratio of the number of farmers and fishermen divided by the total productive age of the population |
| 5 | Level of education | Senior High School (SMA) is the highest level of education | Junior High School (SMP) is the highest level of education | Elementary school (SD) is the highest level of education | The level of education is determined by the majority of the level of education attained by the kelurahan population |
| 6 | Poor family | The proportion of the ratio of poor families is 0.045 – 0.098 | The proportion of the ratio of poor families is 0.099 – 0.151 | the ratio of poor families is 0.152 – 0.203 | The total ratio of poor people based on city classification is divided by the total population. |

The results of calculating the score are obtained from the highest total score and then classification of socio-economic vulnerability is carried out which can be obtained using the formula:

$$Class\ range = \frac{Highest\ value - Lowest\ value}{number\ of\ class} \quad (1)$$

$$Class\ range = \frac{14 - 9}{3} = 1 = 1$$

Determination of socio-economic vulnerability class is done by calculating the highest score out of a total score of 14, the lowest score is 9, and the number of classes is divided into 3 classes. The total score results and class ranges are classified into 3 classes as shown in Table 5.

Table 5. Classification of Socio-Economic Vulnerability Classes

| No | Classification of Socio-Economic Vulnerability Class | |
|---|---|---|
| | Vulnerability Level | Value Range |
| 1 | Low Vulnerability | 9 |
| 2 | Moderate Vulnerability | 11-12 |
| 3 | High Vulnerability | 13-14 |

## 3. DISCUSSION AND DISCUSSION

Based on the scoring criteria in Table 4, the findings are then described for each variable of population density, the proportion of unproductive age (children and the elderly), sex ratio, level of education, livelihoods, and groups of poor people with the assumption that pre-prosperous families scattered in North Pekalongan District. The level of vulnerability of each variable can be seen in the following description.

### 3.1 Research result

The research results of this paper are in the form of a description of the level of vulnerability in 6 (six) variables. The discussion can be started with the Variable Distribution of Population Density and Productive Age Population in the seven kelurahan (village) as shown in Figure 3.

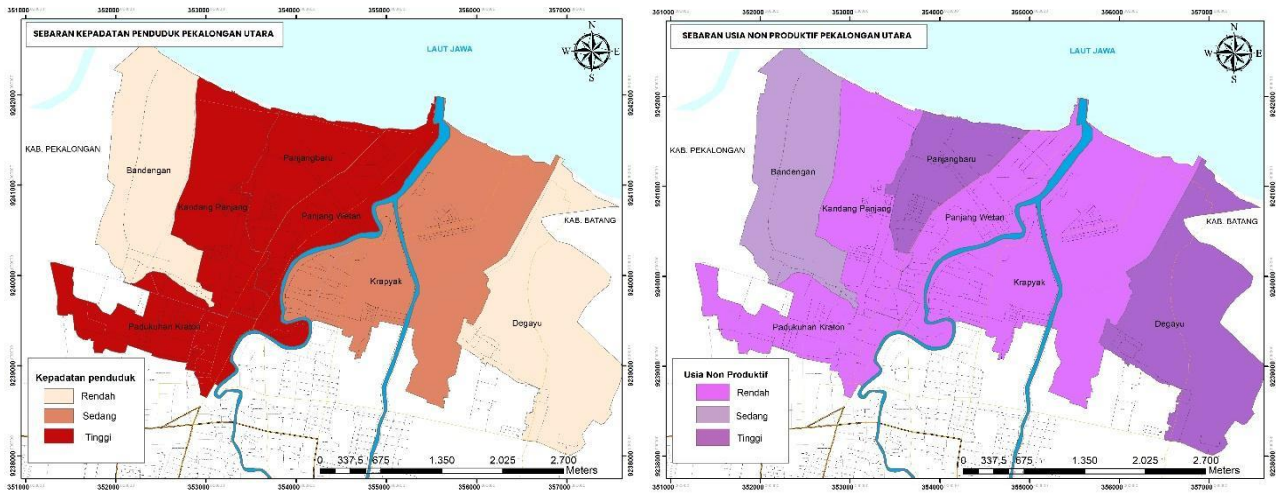



Figure 3. Spatial Pattern of Population Density and Vulnerable Communities (Children and Elderly)

Based on Figure 3, there are various patterns of distribution in terms of population density and vulnerable groups in society (children and the elderly). 4 (four) sub-districts have a high level of density, which are in the sub-districts of Panjang Wetan, Kandang Panjang, Panjang Baru and Padukuhan Kraton which are the most densely populated areas with a density of between 7,436-10,000 people/km $^2$. Meanwhile, Krapyak Village is at a moderate level with a density of between 4,870-7,435 people/km $^2$. It can be indicated that the Degayu and Bandengan sub-districts are less vulnerable to population density conditions, where the population density ranges from 2303-4869 people/km $^2$. Besides that, in Figure 3., it can be seen that there is an imbalance in the proportion of population density in the North Pekalongan District. This is indicated by the composition of the distribution of the population tends to be uneven so that it accumulates in one village. The high population density in an area will contribute value to a high level of social vulnerability in Pekalongan Utara District.

When looking at the variable of non-productive age, Degayu Sub-District together with Panjang Baru Sub-District are also areas of concentration of non-productive age. This kelurahan is included in the most vulnerable classification with a ratio of the proportion of unproductive age between the ratio values of 0.311 - 0.332.

Meanwhile, there is one sub-district that is included in the classification of moderate vulnerability with an unproductive age ratio, namely Bandengan Village. The proportion of the productive age ratio in Bandengan Village is in the range of 0.288 and 0.310. In this context, four sub-districts can be categorized as less vulnerable to the condition of the proportion of vulnerable ages, including Kelurahan Kandang Panjang, Panjang Wetan, Krapyak, and Padukuhan Keraton which have a low level of vulnerability with a proportion between 0.265 to 0.287.

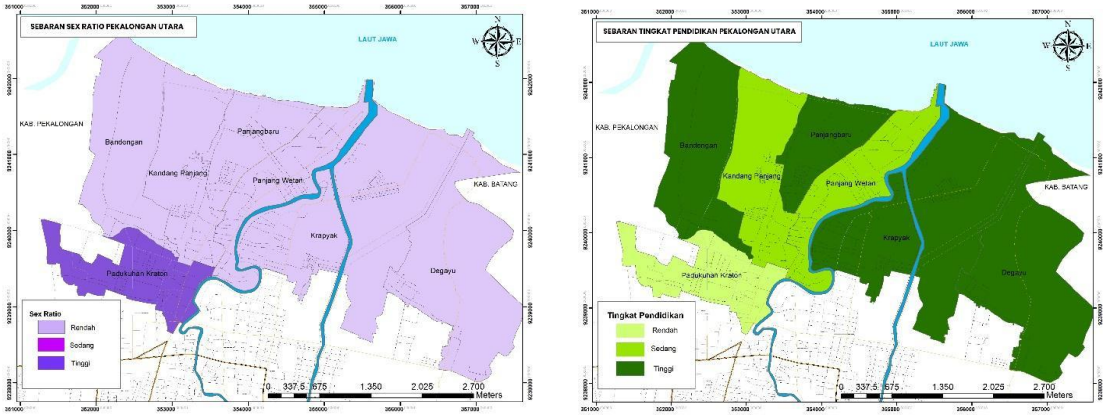



Figure 4. Spatial Pattern of Vulnerable Communities (Women) and Level of Education

This study also calculated the proportion of the ratio between the number of male populations to females. The approach taken is to count the number of males for every 100 females according to Table 4. above. From the available data, the Padukuhan Kraton Village has a larger proportion of women. Thus, the Padukuhan Kraton Village in this area is included in the high vulnerability category. Meanwhile, the other six sub-districts, Degayu, Krapyak, Kandang Baru, Kandang Panjang, Panjang Wetan, and Bandengan, are included in the low vulnerability category because they have a higher proportion of males than females.

In the context of education level, according to Table 4 regarding the scoring criteria, it can be stated that the lower the level of community education, the higher the level of vulnerability and vice versa. This is based on the argument that a high level of education will be directly proportional to the knowledge to survive and adapt. The ability to survive and adapt will reduce the level of vulnerability. From the available data above, it can be seen that Degayu, Krapyak, Panjang Baru, and Bandengan Villages have a high level of vulnerability because the population is dominated by elementary school graduates. While Kelurahan Panjang Wetan and Kandang Panjang are in the medium category because the population is dominated by junior high school graduates. Thus, only Padukuhan Kraton Village is in the low vulnerability category because most of the population has a high school education.

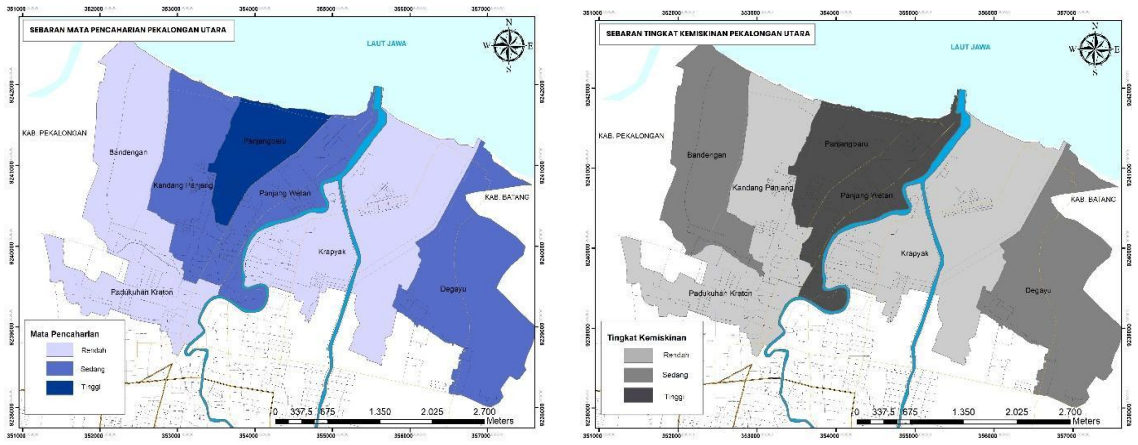



Figure 5. Spatial patterns of economic aspects (livelihood conditions and poverty levels)

Based on the vulnerability assessment from an economic perspective, another aspect studied related to vulnerability is livelihoods. The approach taken is through calculating the proportion of the number of farmers and fishermen to the total population of productive age. This is based on the assumption that the higher the proportion, the higher the level of vulnerability and vice versa. These livelihoods are sensitive to climate change stimuli as well as exposure to hazards that impact land productivity. Based on existing data and referring to Table 4, it is known that Kelurahan Kandang Panjang has a high level of vulnerability because the proportion is 0.940 to 1.170. While Bandengan and Panjang Wetan are included in the moderate vulnerability category because their proportions are between 0.710 -0.930. Thus other kelurahan are included in the low vulnerability category because the proportion of farmers and fishermen only ranges from 0.470 -0.70.

The last variable studied to determine the level of socio-economic vulnerability in the study area is the condition of poverty. The approach used in determining the poverty level is the ratio of the number of pre-prosperous families to the population. The lower the proportion, the better the level of social welfare and the lower the level of vulnerability. Vice versa. Based on the calculations carried out, it can be seen that the Panjang Wetan and Panjang Baru sub-districts are in the high vulnerability category because they have a proportion ratio of poor families between 0.152-0.203 while the Degayu Kelurahan which has a proportion ratio of poor families between 0.099-0.151 is categorized as moderate vulnerability. Thus, three sub-districts fall into the low vulnerability category, namely Kandang Panjang, Krapyak and Padukuhan Kraton because they have a proportion between 0.045-0.098.

Table 6. Socioeconomic Vulnerability Scoring Results

| No | Kelurahan (Village) | Variable | | | | | |
|---|---|---|---|---|---|---|---|
| | | Population Density (Person/Km $^2$) | Children and elderly (index) | Sex Ratio (gender) | Level of education | Livelihoods (index) | Poor families (index) |
| 1 | New Length | 9,327 (Tall) | 0.332 (Tall) | 103.4 (Low) | Elementary Domination (High) | 0.139 (High) | 0.203 (High) |
| 2 | Wetan Length | 10,001 (Tall) | 0.265 (Low) | 105.62 (Low) | Middle School Domination (Medium) | 0.050 (Medium) | 0.155 (High) |
| 3 | Long Cage | 8,657 (Tall) | 0.282 (Low) | 101.85 (Low) | Middle School Domination (Medium) | 0.029 (Medium) | 0.093 (Low) |
| 4 | Degayu | 2,303 (Low) | 0.322 (Tall) | 103.08 (Low) | Elementary Domination (High) | 0.046 (Medium) | 0.121 (Medium ) |
| 5 | Krapyak | 4,879 (Currently) | 0.275 (Low) | 103.08 (Low) | Elementary Domination (High) | 0.043 (Low) | 0.045 (Low) |
| 6 | Banding | 2,786 (Low) | 0.293 (Currently) | 104.65 (Low) | Elementary Domination (High) | 0.029 (Medium) | 0.116 (Medium ) |
| 7 | The Kraton Paddock | 7,653 (Tall) | 0.273 (Low) | 98.87 (High) | SMA Domination (Low) | 0.005 (Low) | 0.090 (Low) |

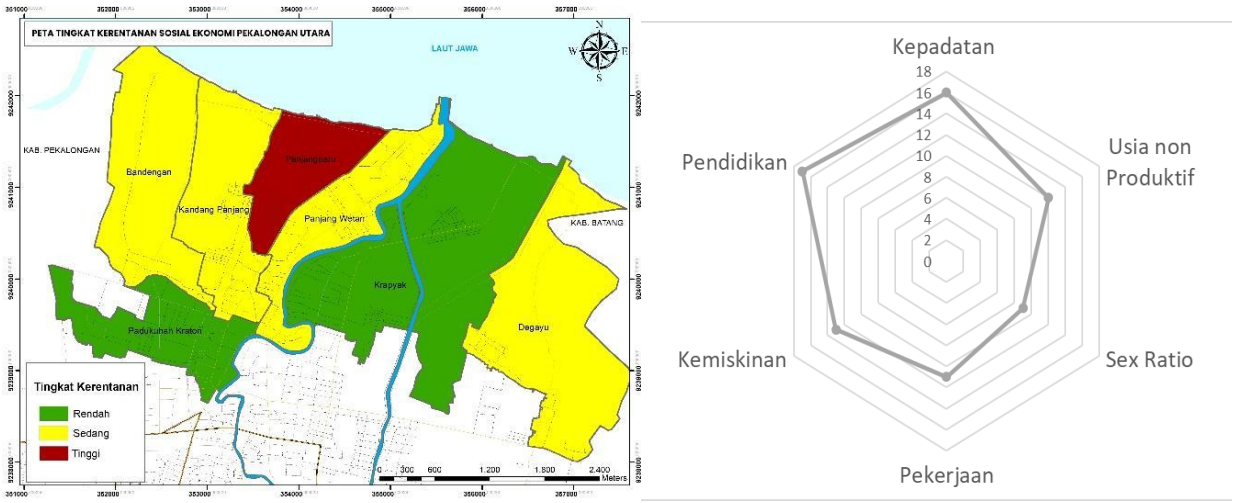



Figure 6. *Radar Chart* of Vulnerability Variable Scoring and Spatial Patterns of Socioeconomic Vulnerability

Based on the diagram above, it can be concluded that there are 6 (six) indicators or variables that can explain the condition of the level of socio-economic vulnerability in Pekalongan Utara District. The education level indicator is the indicator that contributes the most to the vulnerability score. In addition, indicators of population density, poverty or poverty and non-productive age make a significant contribution in assessing socio-economic vulnerability. When referring to the condition of the level of education, this shows that there are still very few people in North Pekalongan District who are highly educated. These conditions will have an indirect effect on other variables, especially the ability of the community to adapt to the dangers of exposure to tidal floods in North Pekalongan District. The condition of the level of education will have an influence on the economic condition of the community, especially the poor who are the most vulnerable to external factors.

Furthermore, high population density contributes a fairly high value to the level of vulnerability in Pekalongan Utara District. Areas that have a high density in areas prone to tidal flooding will experience difficulties in evacuating. In addition, areas with high density will be synonymous with slum settlements. The slums themselves will be interconnected with disturbances in the regional supporting infrastructure systems such as roads, drainage, and sanitation. This condition will have an impact on public health in Pekalongan Utara District.

Furthermore, several indicators have relatively low contribution values among other variables such as *sex ratio*, vulnerable age (elderly and children), and livelihoods. The proportion of sex or gender in North Pekalongan Sub-District experienced a difference from previous years, where the proportion of the male sex was higher than that of the female sex. This condition causes the value contribution given to tend to be low because the proportion of male sex is higher, it can be concluded that community resilience will be better against exposure to tidal flood hazards. This also applies to the non-productive age which contributes a low value, because the proportion of non-productive age tends to be low. The low proportion of vulnerable age will affect the value of vulnerability so that regional responsibility for vulnerable age groups becomes lighter. Meanwhile, in the context of the sex ratio concerning education, the majority of primary and junior high school graduates are women. This fact shows another problem, namely gender equality in education. Although not revealed in this study, social norms that consider education less important for women need to be changed.

Classification is carried out into 3 vulnerability classes spread across 7 (seven) Sub-Districts. Based on the results of the analysis calculation, it is known that those included in the high vulnerability level classification are in Panjang Baru Village, then those included in the moderate level of vulnerability are in Bandengan Village, Kandang Panjang Village, Panjang Wetan Village, Degayu Village, and lastly, those that enter the level low vulnerability, namely Krapyak Village and Padukuhan Kraton Village. The results of the analysis have been supported by validation through field observations, where the new Long Village has a high level of

vulnerability because the area is a densely populated residential area and there are still slums in it. Sub-districts with a low level of vulnerability (Krapyak and Padukuhan Kraton) have the potential for strong community social capital because the majority of the population has graduated from higher education and the majority of the population works outside the agricultural and fishing sectors. This shows that the economic conditions in Krapyak Village and Padukuhan Kraton have a good indication of adapting to tidal flood hazard conditions.

### 3.2 Discussion

Socio-economic vulnerability research in the context of urban development presents a process for identifying, categorizing, calculating, ranking vulnerabilities, and mapping the distribution of vulnerabilities in an area. Based on the data presented in this study, previous work has considered the social, economic, and other supporting aspects as the main variables and indicators. Based on the research results, it is known that there are three classifications of vulnerability levels in Pekalongan Utara District. The educational level variable contributes a strong value in assessing the level of socio-economic vulnerability. Meanwhile, the gender variable through the gender ratio contributes a low value in determining the value of the socio-economic vulnerability level. The new Kelurahan Panjang area has the highest vulnerability value among the other five kelurahan, where the kelurahan has a high population density, the community is dominated by low levels of education, the number of fishermen and farmers is high which affects the high number of poor families.

Adger et al (2007) argue that the livelihoods of people in vulnerable areas are an important aspect in assessing vulnerability and need to be elaborated further because it relates to food insecurity in coastal areas. In line with that, Ahsan and Warner (2014) again stated that community livelihoods and capacity are important challenges that must be faced in balancing the ability to recover from changing conditions and pressures, especially tidal floods due to climate change. In addition, Flanagan et al (2011) argue that regional recovery which tends to be slow is influenced by education level, age, poverty, and population density, this will have an impact on the capacity and capability to recover from the threat of disaster. the vulnerability of the social group concerned depends on their resilience capacity (Malakar and Mishra, 2016). The capacity of individuals and social groups when facing pressure from changing environmental conditions will most likely affect their livelihoods.

Based on some of the results of this perspective, it provides two main implications. First, it has implications for community resilience. Seeing the tendency for coastal urban areas in Java Island to have the same characteristic issues, the use of data from the results of socio-economic vulnerability assessments can assist in formulating policy decisions. The capacity and capability of the community will affect the implications of community resilience in recovering and adapting to the threat of disaster hazards to changes in environmental conditions. then the second implication is that the results of this study have implications for urbanization and sustainability. Handayani et al (2017) stated that the phenomenon of massive urbanization in the northern coastal region of Central Java should diversify livelihoods. This will help them create resilience and sustainability from a socio-economic standpoint. In addition, Faniza and Pradoto (2019) argue that developing coastal areas have great social vulnerability seen in the case of Semarang City, this again shows that the increasingly developing north coast of Java puts pressure on the social aspects of society. In line with this research, North Pekalongan is a coastal area affected by tidal floods, which has an overview of the distribution of social and economic vulnerability which is dominated by moderate to high vulnerability. Therefore, resource allocation must consider important factors in reducing vulnerability in tidal flood prone areas.

Research on social and economic vulnerability often discusses regional vulnerability at a macro scale (cities with more than a million inhabitants) concerning urbanization (Handayani, et al, 2017). Livelihoods from fishermen to other sectors are an indication of changes in coastal areas that are undergoing urbanization (Handayani and Kumalasari, 2015). Meanwhile, Jabareen (2006) argues that population density is an aspect that determines urban survival. North Pekalongan is a sub-district located in a medium-scale city with growing coastal characteristics. Vulnerability research on this micro-scale can be a lesson about social and economic vulnerability, especially in coastal areas affected by tidal floods.

Future study studies will explore how this socio-economic vulnerability assessment can be used as part of the equation regarding preparedness in disaster hazard mitigation. In addition, according to Flagnan et al (2011) this social vulnerability assessment can assist again in targeting disaster management interventions, especially from the socio-economic aspect. presentation of the results of the assessment through mapping of socio-economic vulnerability provides an overview of the spatial distribution in areas that are prone to the threat of flood disasters. The description of the spatial distribution also helps in the process of formulating policies so that the planning program that is carried out does not run partially and completely. The process of assessing the level of vulnerability uses measuring tools that are common, flexible and easy to understand to enable other researchers to be able to provide easily accessible data in various conditions and research areas.

However, using a socio-economic vulnerability assessment has several limitations in seeing the condition of people in vulnerable areas. One limitation is the composition of some small populations which can change rapidly in subsequent years. This limitation can be triggered by government programs related to the control of slum areas which have an impact on the relocation of several communities in the area. therefore it is necessary to make similar research adjustments in response to the possibility of urban regeneration in Pekalongan City. In addition, the use of secondary data in this study is a limitation in exploiting social conditions from the direct perspective of the people in North Pekalongan sub-district. the perspectives of people in vulnerable areas such as community perceptions to social capital are the next important discussion to be studied in more depth.

## 4. CONCLUSION

This research study uses several combinations of data and information through institutional secondary data that are adjusted to the characteristics of the research area to assess socio-economic vulnerability to tidal flood hazards. Vulnerability assessment is carried out using a quantitative process, namely using the scoring method and normalizing the value of each variable. The vulnerability assessment method provides an opportunity to understand how socio-economic variables can play a role in determining the relationship between the phenomenon of urbanization and the hazard of tidal floods due to climate change.

Based on the findings, it was found that the level of social and economic vulnerability to the tidal flood hazard in Pekalongan Utara District was divided into three vulnerability categorization classes. The new Panjang Sub-district received the highest vulnerability score, the Padukuhan Kraton Sub-district received the lowest vulnerability score, and four other sub-districts such as Panjang Wetan Sub-District, Bandengan Sub-District, Kandang Panjang Sub-District and Degayu Sub-District were included in the moderate vulnerability category. In addition, the value contribution that most influences the value of socio-economic vulnerability is education, population density, and poor families. Judging from the results of the assessment, the Panjang Baru sub-district has the highest level of vulnerability because the sub-district has a low level of education, a high population density, a high number of poor people and a high proportion of pond farmers and fishermen among the 6 other sub-districts.

Therefore, the findings provide evidence that gives a broad meaning related to the socio-economic conditions of coastal communities that can have implications for the readiness of an area in creating community resilience in areas prone to tidal floods. In addition, resource allocation and regional growth are also important for maintaining the environment and socio-economic balance of the people of Pekalongan Utara District. Therefore, the most important thing is how to reduce vulnerability due to tidal flood hazards. limitations in this study are the use of secondary data and the composition of the small population. The involvement of primary data needs to be continued in further research, especially to find out community perceptions regarding social capital, capacity, and capability in depth at the same scope scale so that future researchers get a real picture of the community in North Pekalongan District. Thus, this research provides the data needed to make new efforts to overcome and mitigate the dangers of tidal floods due to climate change from a socio-economic perspective, especially in the northern coastal cities of Java Island.

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