Spatial Model of Coastal Community Vulnerability of Puger District to Tsunami Disaster Hazard

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Abstract. Puger coastal region is prone to tsunami and earthquake disasters. Puger District lies in the coastal zone which is directly adjacent to the Indian Ocean. Village areas included in the Coastal District of Puger are villages of Puger Kulon, Puger Wetan, Mojomulyo, and Mojosari. The potential for tsunami disaster on Puger Beach can affect the safety of the coastal communities of Puger. The location of community settlements is close to the beach, with relatively poor understanding of the danger of tsunami. Moreover, the negligence of an established disaster mitigation plans for tsunamis in Puger coastal region causes high vulnerability in case of tsunami; hence, casualties and property loss can affect the economy of the surrounding community. Based on these conditions, the study aims to assess the level of social, economic, physical and environmental vulnerabilities modelled spatially to determine the level of vulnerability of the community with the aid of Arc GIS 10.2 software. The analysis method employs scoring analysis and spatial analysis. The research output is a spatial model in the form of a community vulnerability map to the threat of a tsunami disaster.

Keywords: Spatial Model, Tsunami, Community Vulnerability, Puger

1. Introduction

Indonesia as an archipelago has a total of approximately 18,000 islands with coastlines reaching 92,000 km, making Indonesia one of the largest archipelagic countries in the world [1]. Indonesia's territory is largely a coastal area having a lot of potentials. The location of Indonesia is in the very active four-plate boundary zone leading to very high tectonic and volcanic activity; hence it can potentially cause tsunamis [2].

The Indo-Australian Plate collides with the Eurasian Plate off the coast of the Indian Ocean, Java Island and Nusa Tenggara whereas the Pacific Plate is located in the north of Irian and North Maluku. Around the location of the plate meeting, there is an accumulation of collision energy collected until a point until the earth's layer is no longer able to hold back a pile of energy which then dislodges a tectonic earthquake [3]. The quake is partly centered on the Indian Ocean floor, and some could trigger large ocean waves called tsunamis. The Ministry of Public Works stated that the south of Java is included in Region 4, which means that the southern part of Java Island has high potential to experience earthquakes triggering tsunamis because the point of the earthquake is in the Indian Ocean.

On the other hand, the protection of coastal areas related to mitigation efforts against tsunami wave hazards is very rare. This is due to the fact that the Indonesia has great width of coastline directly opposite to the plates and faults of the earth which has the potential to cause earthquakes and tsunamis.
The Indonesian coast which includes the tsunami-prone criteria stretches from West Indonesia, covering Aceh, Nias, Padang, Bengkulu, Lampung, then Pangandaran, Pacitan, Banyuwangi, Jember to East Nusa Tenggara.

Jember Regency is one of the South Coast coastal areas in East Java which is also prone to tsunamis. Puger coastal region is prone to tsunami and earthquake disasters. Puger District is included in the South Coast coastal zone which is directly adjacent to the Indian Ocean. Village areas included in the Coastal District of Puger are Puger Kulon, Puger Wetan, Mojomulyo, and Mojosari. The potential for a tsunami disaster on Puger Beach can threaten the safety of the coastal communities of Puger. The location of community settlements is close to the coast with poor knowledge and understanding of the threat of tsunami hazards. To make it worse, there is no tsunami disaster mitigation plan in the Puger coastal area, causing high vulnerability in the event of a tsunami disaster. It can greatly cost lives and property loss, affecting the economy of the surrounding community.

Based on these conditions, the study aims to assess the level of social, economic, physical and environmental vulnerabilities modelled spatially to determine the level of vulnerability of the community with the aid of Arc GIS 10.2 software.

2. Methods

The approach taken in this study is a spatial modelling approach which describes the real conditions in the field. The research method of data analysis is to support the process of data modelling and analysis. The analytical method used in the research is scoring analysis and spatial analysis. Variables, sub-variables, and parameters used in the study are taken from the previous research, literature review, and government regulations (as presented in Table 1).

| Variable          | Sub Variables                  | Parameter                                      | Source          |
|-------------------|--------------------------------|------------------------------------------------|-----------------|
| Hazard            | Estimation of Wave Height      | Water depth (bathymetry)                       | [4]             |
|                   |                                | Elevation (topography)                         | [5]             |
|                   |                                | Wave height                                    |                 |
|                   |                                | Flow depth                                      |                 |
|                   |                                | Inundation length (inundation distance)        |                 |
|                   |                                | Height of run-up                                |                 |
|                   |                                | Tsunami hazard scenario                         |                 |
| Vulnerability     | Social                         | Population density                             | [6]             |
|                   |                               | Population growth rate                         | [7]             |
|                   |                               | Female population                              | [8]             |
|                   |                               | Level of education                             |                 |
|                   | Environmental                  | Environmental protection zone (protected forest, green open space, water catchment) |             |
|                   | Physical                       | Built area                                     |                 |
|                   | Economic                       | Poverty level                                  |                 |
|                   |                               | Area of productive land                         |                 |
|                   |                               | Vulnerable labor sector                         |                 |

The analysis used is:

2.1. Scoring Analysis

Scoring analysis is conducted by giving a score on each variable and parameters used in the study. The first step is scoring the parameters of each sub-variable; afterwards, the second scoring will be completed on the sub-variables of each variable. Hence, the final results are obtained in the form of the level of vulnerability of the community to the tsunami disaster. The scoring analysis does not utilize standardized classification or theoretical review because the resulting level is not well distributed. In addition, there
are several indicators which do not have standards. Therefore, a classification calculation is adjusted according to the indicators used in the study as well as the condition of the study area using Equation 1:

\[
\text{Class Length} = \frac{(\text{Max Score} - \text{Min Score})}{3} \quad \text{(1)}
\]

2.2. Spatial Analysis
Spatial analysis is carried out by overlaying threat maps and vulnerability maps based on matrix presented in Table 2 [9]. The spatial analysis is carried out using Geographic Information System tools in the form of ArcGIS 10.2 software.

| Vulnerability | Hazard | High | Moderate | Low |
|---------------|--------|------|----------|-----|
| Low           | Moderate| Low  | Low      |     |
| Moderate      | High   | Moderate | Low   |     |
| High          | High   | High  | Moderate |     |

Table 2. Hazard & Vulnerability Maps Overlay Matrix

Source: Sudibyakto & Priatmodjo (2016)

3. Results and Discussions

3.1. Overview of Puger District
Puger District consists of 12 villages, Mojomulyo, Mojosari, Puger Kulon, Puger Wetan, Grenden, Mlokorejo, Kasiyan, East Kasiyan, Wonasari, Jambearam, Bagon, and Wringin Telu. The villages directly facing the Indian Ocean are Mojomulyo, Mojosari, Puger Kulon, and Puger Wetan Villages. Puger District consists of 37 hamlets, 225 community groups and 657 neighborhood groups. Puger District has an area of 73.53 km2, with land use classification in 2016 consisting of 4,039 ha of rice fields, 933.4 ha of moorlands, 67.2 ha of ponds, 1,895 ha of buildings and courtyards and 7,357 ha of other uses.

Figure 1. Administration Map of Research Study Area

Figure 2. Map of Land Use

3.2. Hazard Analysis
A disaster threat is an event which can cause a disaster [10]. Tsunamis are ocean waves caused by undersea geological processes in the form of earthquakes, volcanic eruptions, landslides, and the fall of meteors in the sea [11]. Potential areas for tsunami hazard are categorized to high, moderate and low hazard potential. Tsunami hazard map provides information about the possibility of a tsunami and the tsunami hazard category classification by the tsunami wave height range (Table 3.) [12]. Table 4 presents an extensive exposure to rural areas by the tsunami hazard level.

Table 3. Classification of Tsunami Hazard Categories
### Wave Height Range (meters) Tsunami Category The Color of Affected Area

| Wave Height Range (meters) | Tsunami Category | The Color of Affected Area |
|---------------------------|------------------|---------------------------|
| 0.1 - <0.5 meters         | Small Tsunami    | Green                     |
| 0.5 - <3.0 meters         | Moderate Tsunami | Yellow                    |
| ≥ 3.0 meters              | Large Tsunami    | Red                       |

Source: InaTEWS (BMKG, 2008)

#### Table 4. Area of Each Village Based on the Level of Potential Disaster Hazards

| Village     | Area Size Based on Potential Danger Level (Ha) |
|-------------|-----------------------------------------------|
|             | High | Moderate | Low |
| Mojomulyo   | 305.15 | 502.27 | 162.85 |
| Mojosari    | 339.55 | 519.10 | 133.90 |
| Puger Kulon | 147.56 | 294.68 | 3.36  |
| Puger Wetan | -     | 361.30 | 170.65 |

Source: GITEWS, 2007

The widest area of the village included in the high, moderate and low tsunami hazard level is Mojosari Village, with a high tsunami hazard area of 339.55 Ha, moderate tsunami hazard of 519.1 Ha, and low tsunami hazard of 133.9 Ha. Puger Kulon village has a high tsunami hazard level of 147.56 Ha, a moderate tsunami hazard level of 294.68 Ha, and a low tsunami hazard level of 3.36 Ha. Mojomulyo Village has a high tsunami hazard area of 305.15 Ha, moderate tsunami hazard level of 502.27 Ha, and a low tsunami hazard level of 162.85 Ha. Puger Wetan village has a moderate tsunami hazard level of 361.3 Ha, and a low hazard level of 170.65 Ha. Mojosari Village has a high tsunami hazard area of 339.55 Ha, moderate tsunami hazard level of 519.1 Ha, and a low tsunami hazard level of 133.9 Ha. The widest area of the village with the lowest tsunami hazard level is Puger Wetan Village with an area of 170.65 Ha and a moderate hazard level of 361.3 Ha.

### 3.3. Vulnerability Analysis

The vulnerability is a condition of a society which causes an inability to deal with disaster threats [5].

#### 3.3.1 Economic Vulnerability

The indicators used in the analysis of economic vulnerability are poverty levels, the area of productive land and vulnerable sector labor as presented in Table 5. Scoring results for the economic vulnerability in each village in the coastal area of Puger Beach show that Mojomulyo Village and Puger Kulon Village have a classification of low economic vulnerability. Mojosari Village has a classification of moderate economic vulnerability to disasters; meanwhile, Wetan Puger Village has a classification of high economic vulnerability.

The high economic vulnerability of Puger Wetan Village comes from high percentage of productive land area, which accounted for 75.73% of the total land area of Puger Wetan Village, including the land area of the agricultural sector, plantation sector, and ponds. The productive land is used by the community as a source of income; hence, if the area of productive land belonging to the community is...
affected by a disaster, the community will suffer from economic resource loss. In addition, vulnerability also comes from high percentage of vulnerable sector labor, which accounted for 46.07% of the total population of Puger Wetan Village, relying on sea fishing. The vulnerable sector affected in the event of a tsunami disaster is the fishery sector in which the residents making their living as fishermen will lose their livelihood for a specific duration.

**Table 5. Economic Vulnerability of Villages in Puger District**

| Indicators                  | Village          |
|-----------------------------|------------------|
| Poverty Level (%)           | Mojomulyo 10.33  |
|                             | Mojosari 10.90   |
|                             | Puger Kulon 5.06 |
|                             | Puger Wetan 4.86 |
| Area of Productive Land (%) | Mojomulyo 40.16  |
|                             | Mojosari 49.27   |
|                             | Puger Kulon 34.81|
|                             | Puger Wetan 75.73|
| Vulnerable Labor Sector (%) | Mojomulyo 6.31   |
|                             | Mojosari 0.00    |
|                             | Puger Kulon 31.18|
|                             | Puger Wetan 46.07|
| Poverty Level Score         | Mojomulyo 3      |
|                             | Mojosari 3       |
|                             | Puger Kulon 1    |
|                             | Puger Wetan 1    |
| Area of Productive Land Score| Mojomulyo 1      |
|                             | Mojosari 2       |
|                             | Puger Kulon 1    |
|                             | Puger Wetan 3    |
| Vulnerable Labor Sector Score| Mojomulyo 1      |
|                             | Mojosari 1       |
|                             | Puger Kulon 3    |
|                             | Puger Wetan 3    |
| Economic Vulnerability Classification | Low            |
|                             | Moderate         |
|                             | Low              |
|                             | High             |

**3.3.2 Environmental Vulnerability**

The environmental vulnerability indicators used are environmental protection zones (Table 6). The wider the scope of the environmental protection zone, such as protected forest, green open space, water absorption, the higher the rain catchment area or water absorption to absorb tsunami water. Therefore, the environmental vulnerability is lower. The width of the environmental protection zone used is the area of green open space in the form of moorings and shrubs because there is no use of forest land in the coastal villages of Puger District. The results of the assessment of the level of environmental vulnerability in the coastal villages of Puger District obtain two levels of vulnerability classification, for villages included in high environmental vulnerability, Puger Wetan Village. However, Mojomulyo Village, Mojosari Village and Puger Wetan Village are included in the level of low environmental vulnerability classification.

**Table 6. Environmental Vulnerability of Villages in Puger District**

| Indicators                  | Village          |
|-----------------------------|------------------|
| Environmental Protection Zone (%) | Mojomulyo 20.81  |
|                             | Mojosari 18.34   |
|                             | Puger Kulon 22.67|
|                             | Puger Wetan 3.76 |
| Environmental Protection Zone Score | Mojomulyo 1      |
|                             | Mojosari 1       |
|                             | Puger Kulon 1    |
|                             | Puger Wetan 3    |
| Environmental Vulnerability Classification | Low            |
|                             | Low              |
|                             | Low              |
|                             | High             |

**3.3.3 Physical Vulnerability**

Indicators used in physical vulnerability include built areas, building density, and road damage. Scoring results for physical vulnerability indicate that Mojomulyo and Mojosari villages have a moderate physical vulnerability classification, Puger Wetan Village has a low classification of physical vulnerability to disasters while Puger Kulon Village has a high vulnerability classification (Table 7).

The high physical vulnerability of Puger Kulon Village comes from the high percentage of the built area of 36.40% from the total land area of Puger Kulon Village. Areas with high built areas are more vulnerable when tsunami disaster occurs. In addition, vulnerability also comes from the high percentage of road damage, which is 36.7% of the total road length in the Puger Kulon village. The road network is one of the supporting infrastructures for disaster, which is used as a disaster evacuation infrastructure. Villages which have a high percentage of damaged roads include areas that are classified as vulnerable because they can inhibit the evacuation process and the process of rescuing themselves when disaster occurs.
Table 7. Physical Vulnerability of Villages in Puger District

| Indicators              | Village                |
|-------------------------|------------------------|
|                         | Mojomulyo   | Mojosari   | Puger Kulon | Puger Wetan |
| Built Area (%)          | 37.1        | 30.1       | 36.4        | 11.9        |
| Building Density (unit/ha) | 13          | 5         | 28         | 53         |
| Road Damage (%)         | 22.9        | 22.6       | 36.7        | 10.3        |
| Built Area Score        | 3           | 3          | 3           | 1           |
| Building Density Score  | 1           | 1          | 2           | 3           |
| Road Damage Score       | 2           | 2          | 3           | 1           |
| Physical Vulnerability Classification | Moderate | Moderate | High | Low |

3.3.4 Social Vulnerability

Indicators of social vulnerability include population density, population growth rate, the percentage of the female population and the percentage of people with low education in the coastal village of Puger District. Puger Kulon Village has a low social vulnerability classification. Puger Wetan Village and Mojosari Village have a classification of moderate social vulnerability to disasters. Meanwhile, Mojomulyo Village has a high classification of social vulnerability (Table 8).

The high social vulnerability of Mojomulyo Village comes from high percentage of the female population, which is 50.22% of the total population of Mojomulyo Village. The population of women is more vulnerable to the tsunami because women tend to need assistance and are physically weak in the evacuation process. Thus, they can increase vulnerability when tsunami disasters occur. In addition, vulnerability also comes from the percentage of non-school residents and the latest education in Elementary School and those who are still in elementary school which is 69.20%. In general, knowledge about disasters is still relatively poor, and the residents are not ready to anticipate disasters, categorized in the population vulnerable to disasters.

Table 8. Social Vulnerability of Villages in Puger District

| Indicators              | Village                |
|-------------------------|------------------------|
|                         | Mojomulyo   | Mojosari   | Puger Kulon | Puger Wetan |
| Population Density (people/ha) | 12           | 12         | 39          | 25          |
| Population Growth Rate | 0.4567 x10^{-2} | 0.4554 x10^{-2} | 0.4558 x10^{-2} | 0.4573 x10^{-2} |
| Female Population (%)  | 50.22       | 50.04      | 49.48       | 49.25       |
| Level of Education (%) | 69.20       | 71.80      | 57.88       | 63.85       |
| Population Density Score | 1           | 1          | 3           | 2           |
| Population Growth Rate Score | 2           | 1          | 1           | 3           |
| Female Population Score | 3           | 3          | 1           | 1           |
| Level of Education Score | 3           | 3          | 1           | 2           |
| Social Vulnerability Classification | High | Moderate | Low | Moderate |

3.3.5 Vulnerability Scoring Analysis

Based on the Head of BNPB Regulation No. 2 of 2012 about General Guidelines for Disaster Risk Assessment, the tsunami vulnerability index has the following weighting concepts.

\[
\text{Vulnerability} = (0.25 \times \text{physical vulnerability score}) + (0.25 \times \text{economic vulnerability score}) + (0.4 \times \text{social vulnerability score}) + (0.1 \times \text{environmental vulnerability score})
\]

Overall, disaster vulnerability assessment in coastal villages in Puger is a result of the level of vulnerability scoring including aspects of physical vulnerability, social vulnerability, economic vulnerability, and environmental vulnerability. Therefore, the overall vulnerability level of the disaster in the coastal villages in Puger District of Jember Regency is presented in Table 9.
Table 9. Community Vulnerability of Villages in Puger District

| Village   | Physical Vulnerability | Social Vulnerability | Economic Vulnerability | Environmental Vulnerability | Total | Classification |
|-----------|------------------------|----------------------|------------------------|-----------------------------|-------|----------------|
|           | Value                  | x Weight             | Value                  | x Weight                    | Value x Weight |               |
|           | (0.25)                 |                      | (0.25)                 |                            | (0.4)            |               |
|           | Value                  | x Weight             | Value                  | x Weight                    | Value x Weight |               |
|           | (0.1)                  |                      |                        |                            |                 |               |
| Mogomulyo | 6                      | 1.50                 | 9                      | 2.25                        | 5               | 2.00           | 0.10          | 5.85          | Moderate      |
| Mojoesari | 6                      | 1.50                 | 8                      | 2.00                        | 6               | 2.40           | 1             | 6.00          | Moderate      |
| Puger Kulon | 8                    | 2.00                 | 6                      | 1.50                        | 5               | 2.00           | 1             | 5.60          | Low           |
| Puger Wetan | 5                    | 1.25                 | 8                      | 2.00                        | 7               | 2.80           | 3             | 6.35          | High          |

3.4. Community Vulnerability of Puger District to the Tsunami Disasters Hazard

The analysis of the vulnerability of the community to the tsunami disaster was carried out by overlaying a threat map and vulnerability based on Table 2; hence, a spatial model was obtained in the form of a community vulnerability map against the threat of a tsunami disaster. The analysis shows that villages with high vulnerability to the tsunami disaster are part of Mojosari Village and part of Puger Wetan Village. A moderate vulnerability village are part of Mojomulyo Village, part of Mojosari Village and part of Puger Wetan Village. Meanwhile, Low vulnerability Village is Puger Kulon Village.

Figure 5. Map of Hazard-Vulnerability Overlay

4. Conclusion

Based on the results of the analysis which have been carried out, it can be concluded that the vulnerability of the Puger District community to the tsunami disaster is as follows:

1. The village in Puger District which is directly adjacent to the Indian Ocean is Mojomulyo, Mojosari, Puger Kulon, and Puger Wetan Villages. Puger Kulon village has a high tsunami hazard level of 147.56 Ha, a moderate tsunami hazard level of 294.68 Ha, and a low hazard level of 3.36 Ha. Mojomulyo Village has a high tsunami hazard area of 305.15 Ha, moderate tsunami hazard level of 502.27 Ha, and a low tsunami hazard level of 162.85 Ha. Puger Wetan village has a moderate tsunami hazard level of 361.3 Ha, and a low hazard level of 170.65 Ha. Mojosari Village has a high tsunami hazard area of 339.55 Ha, moderate tsunami hazard level of 519.1 Ha, and a low tsunami hazard level of 133.9 Ha.

2. Vulnerability in the study was reviewed from four sub-variables: physical vulnerability (built land, building density, and road damage), social vulnerability (population density, population growth rate, female population, and education level), economic vulnerability (poverty level, productive land area, and workers in vulnerable sectors) as well as the vulnerability of the environment (environmental protection zone). Based on the social vulnerability analysis, of the 4 coastal villages in Puger District, 1 of which has high social vulnerabilities with 2 villages have moderate social vulnerability and 1 village has low social vulnerability. Based on the economic vulnerability analysis, of the 4 coastal villages in Puger District, 1 of which has high economic vulnerabilities with 1 village has moderate
economic vulnerability and 2 villages have low economic vulnerability. Based on physical vulnerability analysis, of the 4 coastal villages in Puger District, 1 of them has high physical vulnerabilities, with 2 villages have moderate physical vulnerability and 1 village has low vulnerability. Based on environmental vulnerability analysis, of the 4 coastal villages in Puger District, 1 of which has high environmental vulnerabilities, with 3 villages have low environmental vulnerability. Village with a high level of vulnerability is Puger Wetan Village. Villages with moderate vulnerability are Mojomulyo and Mojosari Villages, and villages with a low level of vulnerability are Puger Kulon Village.

3. Based on the results of the overlay analysis of the hazard map and vulnerability map, villages with high vulnerability to the tsunami disaster are part of Mojosari Village and part of Puger Wetan Village. Moderate vulnerability villages are identified in part of Mojomulyo Village, part of Mojosari Village and part of Puger Wetan Village. Village with low vulnerability is only Puger Kulon Village. Mojosari Village and Puger Wetan Village have a high vulnerability to the tsunami disaster. In terms of threats, they have a higher threat level than other villages because the 1994 tsunami was moderately affected and was located closest to the earthquake epicenter, causing the tsunami in Banyuwangi Regency. Mojosari village also has a high vulnerability to disasters, especially in terms of economic, physical, and social aspects. Therefore, efforts in tsunami disaster risk reduction in Mojosari Village are carried out through improving economic conditions and improving social conditions by prioritizing the education sector including the provision of trainings specifically for women. Puger Wetan Village also has a high vulnerability to disasters from all four aspects of vulnerability. Therefore, tsunami disaster risk reduction efforts in Puger Wetan Village are carried out through improving economic, social and environmental conditions through good environmental management measures.

References

[1] Maryani, Elok. 2008. Model of Mitigation Socialization in Disaster-Prone Local Communities in West Java. Bandung: Research on Higher Education Grants.

[2] Meteorology, Climatology, and Geophysics Agency. 2014.

[3] Fauzi and Wandono. 2005. Determination of Epicenter for Analysis of Tsunami Runoff Risk. Proceedings of the Tsunami Seminar in the Framework for the Application of Research Results for Tsunami Disaster Management in Indonesia (2002-2003-2004). pp 163-169. Jakarta: BPPT Press.

[4] German-Indonesian Cooperation for a Tsunami Early Warning System. 2007

[5] Head Regulation of the National Disaster Management Agency Number 02 of 2012 concerning General Guidelines for Disaster Risk Assessment.

[6] Sumekto, Didik Rinan. 2011. Disaster Risk Reduction Through Analysis of Community Vulnerability and Capacity in Facing Disasters. Yogyakarta.

[7] Habibi, Marbruno & Buchori, Imam. 2013. Spatial Model of Socio-Economic Vulnerability and Institutional Against the Disaster of Mount Merapi. Regional and Urban Planning Engineering Journal. II (1): 1-10. Semarang: Diponegoro University.

[8] Miladan, N. 2009. Study of Semarang's Coastal Area Vulnerability to Climate Change. Thesis. Semarang: Diponegoro University.

[9] Sudibyakto & Anggit Priatmodjo. 2016. Disaster Risk Management In Gunung Padang Cultural Heritage, Ciamis, West Java. Indonesian Disaster Research Journal. II (1): 50-58. Yogyakarta: Gajah Mada University.

[10] Republic of Indonesia Law Number 24 Year 2007 concerning Disaster Management.

[11] Minister of Energy and Mineral Resources Regulation Number 15 of 2011 concerning Guidelines for Volcanic Disaster Mitigation, Soil Movement, Earthquakes and Tsunamis.

[12] Indonesia Tsunami Early Warning System. 2008. Jakarta: Meteorology, Climatology, and Geophysics Agency.