Climate change impact to socio-economy vulnerability in northern Java coastal area

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Abstract. This study aims to identify the north Java coastal areas that are affected by abrasion, to present the result in a map, and to calculate the level of socio-economic vulnerability of people in the north Java coastal areas. Abrasion in the coastal area is an impact of the uprising will affect sea level. This condition will threaten the coastal communities’ life. The research methods were geographical information system (GIS), Livelihood Vulnerability Index (LVI) and Cost-Benefit Analysis (CBA). GIS needed to determine the characteristics of areas with bad climate condition. GIS basically is a special type of information system that considers the representation and manipulation of geographical reality. LVI consists of seven main components to calculate the vulnerability level. CBA used to formulate policy scenario. People in the north Java coastal areas have a high level of socio-economy vulnerability. Mitigation on abrasion needs community awareness, both of people who live there and people who sale along the beach. The government also has a responsibility to mitigate the impact of abrasion in coastal areas.

1. Introduction

Indonesia is one of the largest archipelago countries with more than 17,000 islands and 80,000 kilometers coastline [1]. This condition has placed Indonesia in a vulnerable position to the climate change, especially in term of sea level. IPCC [2] shows that starting on the 19th-century global temperature has risen for 0.74 °C, in average and will keep increasing up to 4.5 °C. These uprising will affect sea level because of the meltdown in artic icebergs. The effect can be seen in term of increased sea tides flood area coverage. In a long-term, more and more small islands will disappear due to increased sea level. As a matter of fact, this condition will threaten the coastal communities’ life. Coastal areas are vulnerable to the effect of climate change, in term of sea level.

Beach abrasion is the shrinkage in coastline from its previous position [3]. In general, 40 percent of total Indonesian coastline is damaged due to abrasion. It is caused by an increase in sea level as the global warming effect and mangrove ecosystem destruction. Other factors that contribute to the destruction of Indonesian beach are a geological aspect, wave power, and whirlwind.

Northern Java coastal area is vulnerable to abrasion. This condition is, by all means, triggering the vulnerability of the coastal communities. Fishermen in the coastal area mostly have several specific problems related to their livelihood [4].
The objectives of this research are mapping the abrasion affected coastal area, doing analysis on the vulnerability of the Northern Java coastal area which caused by climate change, and formulating policy to mitigate climate change impact.

2. Literature review

2.1 Climate change driving force
According to Tjasyono [5] there is a tendency that climate change are affected by human and natural activities. Human activities are deforestation, urbanization, and industrialization. The natural activity including continental shifting, volcanic eruptions, Earth's orbit changes, and El-Nino. Human activity become uncontrolled and leads to irregularities in the system and when the efforts to control it has failed, the impact of such activities can threaten human life [6].

2.2 Environmental management theory
Environmental management becomes our responsibility because the environmental crisis arises due to the impact of human activities. Milner-Gulland [7] states that there are three efforts to balance the interaction between human activities and the environment, namely technological efforts, behaviour or attitude efforts, and comprehension and acceptance effort, which aims to understand and accept natural correction that occurs due to the interaction. Conservation goals, as set forth in the Law of the Republic of Indonesia No. 5 of 1990, aims to pursue the realization of natural resources conservation as well as the balance of its ecosystem. It can support the efforts to improve the welfare of society and the quality of human life.

Conservation is a result of the need to preserve natural resources which quality degraded sharply. Indonesia consist of 73% water area with the enormous ecosystem, therefore conservation measures should be prepared by considering human activities sustainability. The conservation that implemented through marine conservation bureau is based on the active community action to help the marine preservation and conservation fund.

3. Research methods

3.1. Data source
The location of research is on the northern Java coastal area of Demak Regency (Morosari Beach and Purworejo) and Semarang City (Maron beach, Marina beach, Tambak Mulyo, and Tambak Rejo). The respondents are traders and fishermen in Demak and Semarang. Secondary data are average rainfall in the three areas, which is obtained from the Statistical Bureau, and average air temperatures in three areas. While, in five consecutive years are obtained from the National Climatic Data Centre [8].

3.2. Geography information system
This spatial analysis shows existing condition in northern Java coastal area. Spatial data is gathered from the Statistical Bureau [9] such as a basic map of the location, abrasion, and rainfall. Data processing starts with data tabulation and followed by data construction. The next steps are doing spatial analysis and presenting on the graphic form on the thematic map.

3.3. Vulnerability index

3.3.1. Livelihood vulnerability index (LVI) approach. LVI is developed by Hahn et al. [10], which consist of seven main components, namely Social Demographic Profile (SDP), Livelihood Strategy (LS), Health (H), Social Network (SN), Food (F), Water (W), Natural Disaster (ND) and Climate Variability. LVI indicators as presented above is developed into several indicators or sub-components based on the literature review of its main component.
LVI is calculated using balanced weighted average approach [11]. By using this measurement, each of the sub-components will have the same contribution to the overall index, even though each of the main components consists of a number of different sub-components. Each sub-component is calculated using a different scale. Thus, the result should be standardized in order to convert the result into a more general index. By converting the result into an index, the overall result can be calculated. Therefore, to convert the scale of each sub-component obtained from the life expectancy index [12], The scale of LVI values ranges from 0 to 0.2 refer to ‘not vulnerable’, 0.21 to 0.4 refer to ‘moderate’, and 0.41 to 0.5 refer to ‘very vulnerable’ [10].

3.3.2. LVI – IPCC approach (livelihood vulnerability index – an intergovernmental panel of climate change). According to IPCC (2007) [2] LVI-IPCC index is an alternative option to calculate LVI by combining the definition of vulnerability. The exposure of population is measured using the number of floods occur for the last five years. Climate variability is measured using the average of the standard deviation of the maximum and minimum value of monthly air temperature for the last five years. The adaptive capacity measured using demographic profile in each area such as a number of females as the head of family, occupation, and social network. Sensitivity is measured using the status of food availability, water condition, and health level in a certain area. The main difference between LVI-IPCC and LVI is in the integration of its main component. The scale of LVI-IPCC between (-1) to (-0.4) which refer to ‘not vulnerable’, (-0.41) to 0.3 refer to ‘moderate’, and 0.31 to 1 which refer to ‘very vulnerable’.

3.4. Cost-benefit analysis

3.4.1. Net present value (NPV). NPV refers to the discounted net benefit using the Social Opportunity Cost of Capital (SOC) as the discount factor. NPV estimation needs investment costs, operating costs, and maintenance as well as the estimated benefits. The criteria are NPV > 0 means go project, NPV < 0 means no-go project, and NPV = 0 means Break-even point [13].

\[
NPV = \sum_{i=1}^{n} NB_i (1 + i)^{-n} NPV = \sum_{i=1}^{n} B_i - C_i = \sum_{i=1}^{n} N B_i
\]  

Where:  
NB = Benefit – Cost  
C = Investment + operational cost  
i = discount factor  
n = year

3.4.2. The internal rate of return (IRR). IRR refers to a discount rate that provides the results of NPV = zero [13].

\[
IRR = i_1 + \frac{NPV_1}{(NPV_1 - NPV_2)} (i_2 - i_1)
\]

Where:  
i_1 = discount rate for NPV_1 and i_2 = discount rate for NPV_2

If IRR > SOC project is feasible, IRR = SOC project is on Break Even Point, and IRR < SOC project is not feasible. To determine the IRR, firstly, the NPV1 and NPV2 should be calculated through trial and error. If the NPV1 discounted factor is positive, the NPV2 must be greater than SOC, vice versa. From these experiments, we will obtain the IRR value that is between the positive NPV and negative NPV, thus it defines NPV = 0.

3.4.3. Net Benefit Cost Ratio (Net B/C). Net B/C is the ratio between the positive discounted net benefit with a discounted net negative benefit [13].

\[
NetB/C = \frac{\sum_{i=1}^{n} NB_i (+)}{\sum_{i=1}^{n} NB_i (-)}
\]
If Net B/C > 1 means the project is feasible, Net B/C < 1 means the project is not feasible, and Net B/C = 1 means break-even point.

3.4.5. Payback period (PBP). Payback Period is a specific period of time that indicates the cumulative flows that equal to present value of the amount of the initial investment. PBP is used to determine time range needed to recover the initial investment of project [13].

\[
PBP = T_{p-1} + \frac{\sum_{i=1}^{n} I_i - \sum_{i=1}^{p} B_{i|p-1}}{B_p}
\]

Where:
- \( PBP \) = Pay Back Period
- \( T_{p-1} \) = \( t-1 \) before PbP
- \( I_i \) = Discounted investment
- \( B_{i|p-1} \) = discounted benefit before PbP
- \( B_p \) = Benefit on PbP

4. Results

4.1 Mapping of abrasion level in Java
The study area is Semarang and Demak Regency. The abrasion level is categorized by heavy, medium, and low. The heavy level happens in Rembang, the medium is Pekalongan and Demak, and low is Tegal, Kendal, Semarang, Jepara, Pati. Figure 1 is shown the abrasion map in Java island. High level is shown in red color, the medium is yellow, and low is green.

![Figure 1. Map of Abrasion in Java coastal area](https://example.com/figure1)
Source: modified data, 2017

4.2 LVI in Northern Java Coastal Area
LVI result shows that the fishermen and trader’s livelihood is vulnerable to climate change impact and the value of each component serve on table 1. The LVI-IPCC result, as an alternative method developed from LVI, is shown in table 2.
Table 1. Index of LVI

| Main Component (MC)                  | Index of MC | Sub-component (SC)                                      | Index of SC | Category    |
|-------------------------------------|-------------|---------------------------------------------------------|-------------|-------------|
| Socio-demography profile            | 0.213       | Number of dependency                                    | 0.214       | Vulnerable  |
|                                     |             | Householder women (%)                                   | 0.029       |             |
|                                     |             | Average age of women householder                         | 0.559       |             |
|                                     |             | Head of household has no education                       | 0.108       |             |
|                                     |             | Households whose members need help                       | 0.157       |             |
| Livelihood strategy                 | 0.390       | Households with members working outside the city (%)    | 0.314       | Vulnerable  |
|                                     |             | Households whose main income on agriculture (%)         | 0.578       |             |
|                                     |             | Average index of farm livelihood classification          | 0.278       |             |
| Health                              | 0.199       | Average time required (minutes)                          | 0.250       | Not vulnerable |
|                                     |             | Households whose family members have a chronic illness (%) | 0.147           |             |
| Food                                | 0.474       | Households with the most food sources are from own farmland (%) | 0.892       | Very vulnerable |
|                                     |             | Average number of households in a month that has a difficulty to eat | 0.002       |             |
|                                     |             | Households that do not store crops (%)                  | 0.529       |             |
| Water                               | 0.236       | Households utilizing natural water resources (%)         | 0.892       | Vulnerable  |
|                                     |             | Average time required to go to a water source (minutes) | 0.039       |             |
|                                     |             | Households with consistent water supply (%)             | 0.00        |             |
|                                     |             | The contrary to the average amount of water/liters stored/household | 0.011       |             |
| Social network                      | 0.563       | Ratio of receiving                                      | 0.389       | Very vulnerable |
|                                     |             | Ratio of money lending                                   | 0.428       |             |
|                                     |             | Households who have never gone to local government to seek support in the past year (%) | 0.873       |             |
| Natural disasters and climate variability | 0.436   | The average number of flood disaster in the last 5 years | 0.121       | Very vulnerable |
|                                     |             | Households who do not receive warnings of flood disasters arrival (%) | 0.922       |             |
|                                     |             | Households suffering flood disaster over the last 5 years (%) | 0.147       |             |
|                                     |             | Average standard deviation of temperature (monthly) based on daily temperature |             |             |
|                                     |             | a. maximum                                              |             |             |
|                                     |             | b. minimum                                              |             |             |
|                                     |             | Average standard deviation from average rainfall/month   |             |             |

LVI Value: 0.359 Vulnerable

Source: Primary data, 2018

The overall LVI index for the northern Java coastal area is 0.359. It indicates that fisherman and trader in the area is vulnerable to climate change impact.
Table 2. Calculation of LVI-IPCC

| Factor contributor to IPCC | Index of MC | Weight of SC | Value of factor contributor | Category          |
|----------------------------|-------------|--------------|-----------------------------|-------------------|
| Exposure                   | 0.436       | 6            | 0.436                       | Very vulnerable   |
| Adaptive capacity          | 3.924       | 11           | 0.357                       | Very vulnerable   |
| - Social-demography        | 0.213       | 5            |                             |                   |
| - Livelihood strategy      | 0.390       | 3            |                             |                   |
| - Social network           | 0.563       | 3            |                             |                   |
| Sensitivity                | 2.776       | 9            | 0.308                       | Very vulnerable   |
| - Health                   | 0.199       | 2            |                             |                   |
| - Food                     | 0.474       | 3            |                             |                   |
| - Water                    | 0.236       | 4            |                             |                   |
| Index value of LVI-IPCC    |             |              | 0.024                       | Vulnerable        |

Source: IPCC (2007) [2]

The overall value of LVI-IPCC method is 0.024. It indicates that fishermen and trader’s livelihood in northern Java coastal area is vulnerable to climate change impact.

4.3. Cost-benefit analysis

This analysis is for mangrove development in northern coastal Java area by 1,832 hectares which is as one of mitigation choice of abrasion. Economical approach argues that investment of costs and estimation can be expressed in monetary value. The discount rate is 12 percent. It is an interest rate that government imposed on the investment projects. The expected value of the project is 5 years. Table 3 and table 4 are shown the calculation of cost and benefit of mangrove.

Table 3 Calculation of cost

| Cost      | Explanation                              | Rupiahs         |
|-----------|------------------------------------------|-----------------|
| Fish      | Area 12,970 Ha:                          | 17,480,757.98   |
|           | Production cost = IDR 123,758,423         |                 |
| Firewood  | Area 12,970 Ha:                          | 60,001,007.76   |
|           | Firewood production = IDR 219,436         |                 |
| Shrimp    | Area 782.34 Ha:                          | 815,573,588.06  |
|           | Shrimp production = 2,982.72 Kg seeds shrimp = IDR 1,000 | |
| Cost of Mangrove | Cost per Ha = IDR 636,000 | 1,165,152,000.00 |
|           | COST Year 1                              | 2,058,207,353.80 |
| Fish      | Area 12,970 Ha:                          | 17,480,757.98   |
|           | Production cost = IDR 123,758,423         |                 |
| Firewood  | Area 12,970 Ha:                          | 60,001,007.76   |
|           | Firewood production = IDR 219,436         |                 |
| Shrimp    | Area 782.34 Ha:                          | 815,573,588.06  |
|           | Shrimp production = 2,982.72 Kg seeds shrimp = IDR 1,000 | |
| Cost of Mangrove | Cost per Ha = IDR 100,000 | 183,200,000.00  |
|           | COST Year 2,3,4,5                         | 1,076,255,353.80 |

Source: primary data, 2018

Cost of development 1,832 hectares’ mangrove area is about 2 billion for the first year and 1 billion rupiahs, for year 2-5. Total cost for five years is about 3 billion. Benefit of development 1,832 hectares’ mangrove area is about 2.4 billion for five years.
Table 4. Calculation of benefit

| Benefit                  | Explanation                                           | Rupiahs       |
|--------------------------|-------------------------------------------------------|---------------|
| Shrimp woof              | Area 782.34 Ha:                                        | 181,599,968.10|
|                          | Shrimp Production = 2,982.72 Kg                        |               |
|                          | 1 Kg = 2 Kg woof                                       |               |
|                          | Price = IDR 13,000                                     |               |
| Shrimp production        | Area 782.34 Ha:                                        | 279,384,566.30|
|                          | Shrimp production = 2,982.72 Kg                        |               |
|                          | Shrimp price per kg = IDR 40,000                       |               |
| Fish production          | Area 12,970Ha:                                         | 336,973,819.06|
|                          | Fish production = 6,601 Kg                            |               |
|                          | Fish price per kg = IDR 21,800                        |               |
| Firewood                 | Area 12,970 Ha:                                        | 298,725,373.13|
|                          | Wood Production = 115 cords                           |               |
|                          | 1 cords of wood = IDR 9,500                           |               |
| Indirect Benefit         | Break Waters                                          | 954,604,514.67|
|                          | Area 150m×20m×10m:                                     |               |
|                          | Value = IDR 1,563,217,000                             |               |
|                          | Depreciation = 20 years                               |               |
| Choice Benefit           | Benefit of diversity, benefit transfer, USD 1,500 km²·year⁻¹ | 357,240,000.00|
|                          | Wide Ha = 15 USD                                       |               |
|                          | 1 USD = IDR 13,000                                     |               |
| TOTAL BENEFIT            |                                                       | 2,408,528,241.25|

Source: data calculation, 2018

Table 5 shows the calculation of Net Present Value, Internal Rate of Return (IRR), Net Benefit Cost Ratio (Net B/C), and Payback Period (PBP)

Table 5. Calculation of NPV, IRR, Net B/C, and PBP

| Years | Benefit       | Cost     | B/C  | NB   | NPV (12%) | PBP   | NPV (13%) | BCR |
|-------|---------------|----------|------|------|-----------|-------|-----------|-----|
| 1     | 2,408,528,241 | 2,058,207,354 | 1.17 | 350,320,887 | 312,486,232 | 312,486,232 | 310,033,985 | 1.01 |
| 2     | 2,408,528,241 | 1,076,255,354 | 2.24 | 1,332,272,887 | 1,061,821,491 | 1,374,307,723 | 1,043,169,671 | 1.02 |
| 3     | 2,408,528,241 | 1,076,255,354 | 2.24 | 1,332,272,887 | 948,578,296 | 2,322,886,019 | 923,265,111 | 1.03 |
| 4     | 2,408,528,241 | 1,076,255,354 | 2.24 | 1,332,272,887 | 845,993,284 | 3,168,879,302 | 816,683,280 | 1.04 |
| 5     | 2,408,528,241 | 1,076,255,354 | 2.24 | 1,332,272,887 | 755,398,727 | 3,924,278,030 | 723,424,178 | 1.04 |
|       |               | 12,042,641,206 | 6,363,228,769 | 2.02 | 3,924,278,030 | 3,816,576,225 |

Source: data calculation, 2018

NPV calculation resulted 3,924,278,030, indicating that mangrove is feasible. This analysis uses a discount factor of 12 and 13 %, thus that IRR = 12.51, which explains that IRR is bigger than the social discount rate (12 percent). Net BC calculation using NPV₁ (discount factor 12 percent) and NPV₂ (discount factor 13 percent), and the result is 1.03, more than 1, thus mangrove project is feasible. Based on NPV value, the PBP calculation shows that the initial investment will be paid-back for 5 years

4. Conclusions
The study areas are in northern Semarang and Demak Regency. Identification of these areas that suffer abrasion, due to the climate change shows abrasion level in northern Semarang is categorized in low level, while Demak is in medium level.
The calculation result of the social-economy vulnerability of the society who lives in the northern coast zone of Java indicates vulnerability level of traders and fishermen in the northern coast of Java can be categorized as ‘vulnerable’ with an index value of 0.359. The calculation result based on LVI-IPCC it can be categorized as ‘not vulnerable’ with an index value of 0.024.

Policy implementation for climate change mitigation is the development of 1,832 hectares’ mangrove. The result of cost-benefit analysis shows the project is feasible.

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