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SCENARIO FOR CLIMATE CHANGE MITIGATION FOR TWO BIG CITIES IN CENTRAL JAVA, INDONESIA

Evi Gravitiani[1]*, Suryanto[1], Rosalina[2]

[1]*Faculty of Economics and Business, Sebelas Maret University, Central Java, Indonesia*
[2]*Magister of Economics and Development Studies Program, Faculty of Economics and Business, Sebelas Maret University, Central Java, Indonesia*

ABSTRACT

This research aimed to map the poor climate condition of cities in Central Java, Indonesia and formulate alternative scenarios for climate-change mitigation. Geographic Information System (GIS) for mapping the condition and Benefit-Cost Analysis (BCA) for formulating the alternative scenarios were used. The scenarios were planting trees and developing city forests in Semarang and Surakarta. This research contributed to empirical study, methodology, and policy implications. The findings were related to spatial analysis and alternative scenarios for climate-change adaptation. The spatial analysis performed with GIS showed that several big cities were more polluted than other areas in Central Java Province. This result justified why this empirical study was focused on these areas. The Benefit-Cost Analysis showed the alternative scenarios proposed. The policy implication should be executed by considering the proposed scenarios.

Keywords: Alternative scenarios; Benefit cost analysis; Climate change; Geographic information system; Mitigation

1. INTRODUCTION

Climate change occurs as a natural process, and human activities are involved in this process. The rise of earth's temperature causes ice to melt resulting in sea level rise, variability in nature temperature, and global warming. It causes arid paddy fields, damaged ecosystem, clean water shortage, biodiversity degradation, forest fires, and disease. Stern (2007) said that climate change is a part of economic problems. When developed countries ignore the emission effects, it is estimated that the loss is 14 per cent of global Gross Domestic Product (GDP) in the 21st century. The replacement cost is about two to five per cent, and adaptation cost is 0.5 per cent of developed countries' GDP.

Indonesia has 132.4 million hectares of forest for CO2 (carbon sink) reserve. Forest is important because it shares 85 percent on emissions. Community involvement is done by reforestation and tree planting.

This research focused on people's Willingness to Pay (WTP) for climate-change impacts in urban areas. WTP is also used to analyze individual characteristics and personal motives related to other people's interest and alternative to avoid the risk.

Previous studies on mapping by Saptutyningsih and Suryanto (2009), Sen, et al. (2010), Yusuf, et al. (2010), and Cowelland Zeng (2003) used GIS to map areas vulnerable to

*Corresponding author's email: e_gravity2000@yahoo.com

flood in Daerah Istimewa Yogyakarta province, typhoon, climate change in Southeast Asia, and modelling of vulnerability of weather change, respectively.

Le Van An, et al. (2006) conducted research on community participation to overcome typhoon. Socio-economic condition has significant influence on decision-making process by stakeholders. Sen, et al. (2010) found the gap on need and socio-economic condition to overcome the disaster. The community condition influences its ability to adapt.

Vulnerability to climate change in South East Asia mostly occurs in regions with low to middle income levels (Yusuf and Fancisco, 2010). Dell, et al. (2008) used panel data to analyze the impact of long-term climate change. This study found that the impact impaired economic growth in poor countries.

Choice Modelling (CM) was used by Chaisemartin & Mahe (2009) to estimate people's awareness to pay for planting trees as a climate-change mitigation strategy. Roson (2003) used Computable General Equilibrium (CGE) to perform an economic analysis on climate change. Cost-Benefit Analysis (CBA) and Multi Criteria Analysis (MCA) were used by Brouwer and Van Ek (2004) to control floods. The study indicated that traditional control is more effective than technical control such as building a new dam.

2. METHODOLOGY/ EXPERIMENTATION

2.1. Geographic Information System (GIS)

Geographic Information System (GIS) is a set of hardware, software, geographical and personal data that shows information on geographical reference. GIS can be used for various purposes such as accessing potential risk (Connors, 2006), identifying earthquake and tsunami in airports and harbours (Wood and Good, 2004), and estimating social vulnerability on earthquakes (Rashed, 2003) and rainfall characteristics to minimize risk (Dai, 2003). Parson, et al. (2004), Zerger (2002), and Cowell and Zeng (2003) used GIS to identify flood risk and mitigation and the risk model.

In this study, GIS was used to map the areas vulnerable to climate change in two big cities in Central Java Province, Surakarta and Semarang. GIS is a set of computers, software, geographical data, and operators. It is designed to collect, save, update, manipulate, analyze, and show spatial information. Every region has unique and potential risk that can be accessed by GIS. GIS maps the information of climate condition in urban areas by geometric coordinates, identifies the relation between several objects in the map, and processes geometric attributes in spatial content.

2.2. **Benefit cost analysis (BCA)**

Benefit Cost Analysis (BCA) is used to choose mitigation alternatives. It is useful to simulate the policy of flood mitigation in vulnerable areas. Mitigation projects were selected based on the availability of funding, time, and human resources. Maximum benefit and optimum cost are major consideration of project choices because they are related to the constraint of investment capability.

Analysis on investment criteria can be done by mutually exclusive alternative project and cross over discount rate analysis. Mutually exclusive alternative project is the activity of selecting one project due to some constraints. Cross over discount rate analysis is a tool for choosing one project if the social opportunity cost (SOCR) as a discount factor is difficult to calculate. BCA on investment analysis needs several criteria such as:

2.2.1. Net Present Value (NPV)

NPV is discounted net benefit, with SOCR of capital as discount factor.

$$NPV = \sum_{i=1}^{n} NB_i (1+i)^{-n} \tag{1}$$

or

$$NPV = \sum_{i=1}^{n} \frac{NB_i}{(1+i)^n} \tag{2}$$

or

$$NPV = \sum_{i=1}^{n} \overline{B_i} - \overline{C_i} = \sum_{i=1}^{n} N\overline{B_i} \tag{3}$$

Where:
NB = Net benefit = Benefit – Cost
C = Investment cost + Operation cost = discounted benefit= discounted cost
i = discount factor
n = time (year)

Criteria:
NPV > 0 (zero) → project is feasible
NPV < 0 (zero) → project is not feasible
NPV = 0 (zero) → project is on Break Even Point condition
Total Revenue = Total Cost, in present value

NPV estimation needs investment data, operation and maintenance costs, and benefit.

2.2.2. Internal Rate of Return (IRR)

IRR is discount rate of NPV = 0 (zero).
If IRR > SOCC → project is feasible
If IRR < SOCC → project is not feasible
If IRR = SOCC → project is on Break Even Point condition,
NPV_1 and NPV_2 are needed to determine IRR, by a trial and error method. If NPV_1 is positive, the second discount factor must be higher than SOCC, and vice versa. IRR lies between the positive and negative values of NPV.

$$IRR = i_1 + \frac{NPV_1}{(NPV_1 - NPV_2)}(i_2 - i_1) \tag{4}$$

in which i_1 = discount rate of NPV_1
i_2 = discount rate of NPV_2

2.2.3. Net Benefit Cost Ratio (Net B/C)

Net B/C is the ratio of positive discounted net benefit to negative discounted net benefit.

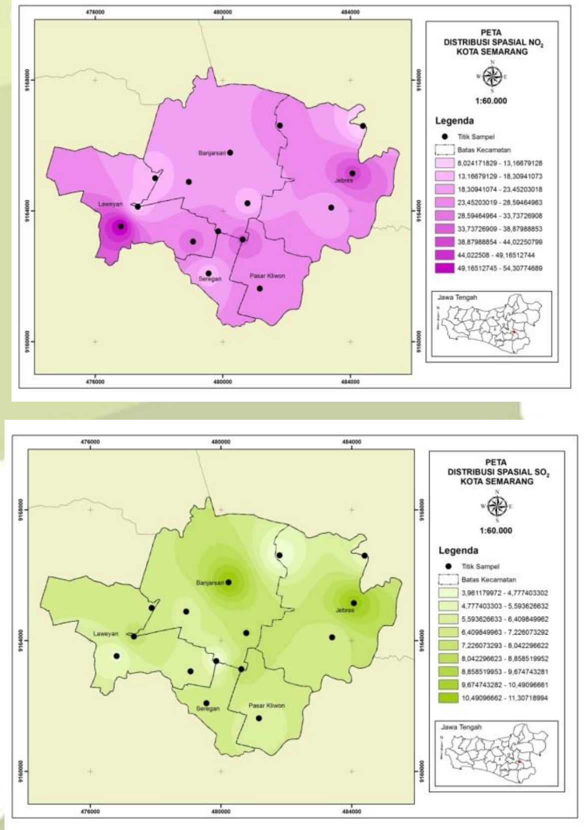
$$NetB/C = \frac{\sum_{i=1}^{n} N\overline{B_i}(+)}{\sum_{i=1}^{n} N\overline{B_i}(-)} \tag{5}$$

If:
Net B/C > 1 → project is feasible
Net B/C < 1 → project is not feasible
Net B/C = 1 → project is on Break Even Point condition, cash inflows = cash outflows

3. RESULTS

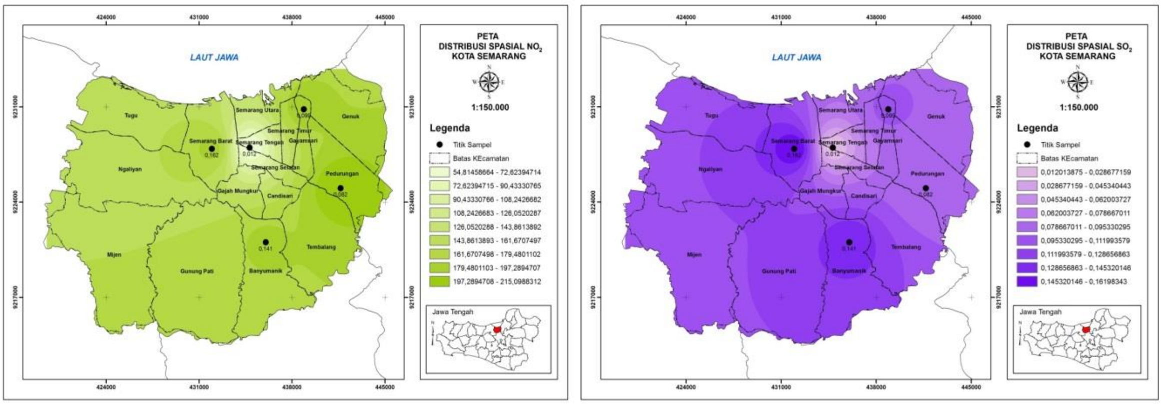
3.1. Analysis of Study Area

Based on the survey, in Surakarta air, NO_2 content was 24.32 µg/Nm^3, SO_2 was 6.91 µg/Nm^3, and O_3 was 3.73 µg/Nm^3 on average. They were below the threshold level of 316 µg/Nm^3 for NO_2, 632 µg/Nm^3 for SO_2, and 200 µg/Nm^3 for O_3. The survey was conducted in 15 monitoring points as shown in Figure 1.



Source: estimation of secondary data, 2015
Figure 1. Spatial Mapping of NO_2 and SO_2 in Surakarta

In Semarang, NO_2 content in the air was 165.94 µg/Nm^3 and SO_2 was 0.10 µg/Nm^3 in average. They were also below the threshold levels. The survey was conducted in four monitoring stations as shown in Figure 2.



Source: estimation of secondary data, 2015

Figure 2. Spatial Mapping of NO_2 and SO_2 in Semarang

3.2. Benefit Cost Analysis

Benefit is estimated from pollutants' price conversion of NO_2 and SO_2. NO_2 content was 24.32 µg/Nm^3 and SO_2 was 6.91 µg/Nm^3, which were two per cent of the threshold for NO_2 (316 µg/Nm^3) and four per cent of SO_2 (632 µg/Nm^3). The conversion price was IDR 0.13 for NO_2 and IDR 0.25 for SO_2 per ton. The price was based on CO price, which was US$ 6 per ton. Benefit estimation is calculated through tree absorptions multiplied by the conversion price of NO_2 and SO_2. The total benefit was IDR 1,925,466 in Surakarta and IDR 5,774,028 in Semarang.

The cost was estimated using seed price and conservation. NO_2 absorbent trees were raintree (*trembesi*) (TR), red acalypha (*akalipa*) (AM), and red mussaenda (*nusaindah*) (NM). The seed prices were IDR 25,000 for raintree, IDR 31,000 for red acalypha, and IDR 100,000 for red mussaenda. SO_2 absorbent trees were *jambu daun lembar* (JM), *kolak* (KL) and *ficus* (FC). The seed prices were IDR 50,000 for *jambu daun lembar*, IDR 85,000 for *kolak*, and IDR 3,500 for *ficus*.

In Surakarta, the total cost for seeds of NO_2 absorbent trees was IDR 156,000 and IDR 883,600 for SO_2 absorbent trees. The cost was estimated by calculating the number of trees and their ability to absorb pollutants. In Semarang, the total cost for seeds was IDR 450,000, comprising IDR 156,000 for NO_2 absorbent trees and IDR 294,500 for SO_2 absorbent trees. The cost for conservation was IDR 4,417,500 for five districts in Surakarta and IDR 8,970,028 for 16 districts in Semarang. The estimation of Benefit-Cost Analysis is shown in Table 1 for Surakarta and Table 2 for Semarang.

Table 1. Benefit Cost Analysis for Surakarta.

	BENEFIT	**COST**	**B/C**	**NB**	**DF (12%)**	**NPV (12%)**	**DF (13%)**	**NPV (13%)**	**IRR**	**BCR**
Year 1	1,925,466	5,417,500	0.36	(3,492,034)	0.892	(3,114,895)	0.885	(3,090,450)	12.502	
Year 2	1,925,466	500,000	3.85	1,425,466	0.797	1,136,096	0.783	1,116,140	12.504	
Year 3	1,925,466	500,000	3.85	1,425,466	0.712	1,014,932	0.693	987,848	12.507	
Year 4	1,925,466	500,000	3.85	1,425,466	0.635	905,171	0.613	873,811	12.509	
Year 5	1,925,466	500,000	3.85	1,425,466	0.567	808,239	0.543	774,028	12.511	
	9,627,329	7,417,500	3.15			**749,543**		**661,376**	**12.531**	**1.133**

Source: estimation, 2015

Table 2. Benefit Cost Analysis for Semarang.

	BENEFIT	COST	B/C	NB	DF (12%)	NPV	DF (13%)	NPV (13%)	IRR	BCR
Year 1	25,039,661	25,640,000	0.98	(600,339)	0.892	(535,502)	0.885	(531,300)	12.502	
Year 2	25,039,661	1,600,000	15.65	23,439,661	0.892	20,908,178	0.885	20,744,100	12.502	
Year 3	25,039,661	1,600,000	15.65	23,439,661	0.797	18,681,410	0.783	18,353,255	12.504	
Year 4	25,039,661	1,600,000	15.65	23,439,661	0.635	14,884,185	0.613	14,368,512	12.509	
Year 5	25,039,661	1,600,000	15.65	23,439,661	0.567	13,290,288	0.543	12,727,736	12.511	
			10.76			**67,228,559**		**65,662,304**	**12.506**	**1.024**

Source: estimation, 2015

4. CONCLUSION

The NO2 and SO2 contents in the Surakarta and Semarang air are below the threshold. Surveys are conducted in 15 monitoring stations in Surakarta and 4 stations in Semarang. Planting trees and city forest are one of the alternative scenarios for climate-change mitigation for the two big cities, Surakarta and Semarang, in Central Java Province. Estimation using Benefit Cost Analysis shows that this scenario is feasible in both cities.

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