Optimization Model for Predicting Green Area in Jakarta to Minimize Impacts of Climate Change

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Abstract

Some studies about climate change in Jakarta revealed that air pollution and water supply has reached a critical level, and one of the efforts to reduce that climate change impact is to increase green area. Under Indonesian Law No. 26/2007 the proportion of ideal green area in big cities like Jakarta is 30% of the total city areas, unfortunatelly at this time the green area in Jakarta is only 9.84%. The effort to increase green area in Jakarta requires huge funds, since the price of land in Jakarta is very expensive. On the other side, the green space is critical requirement to provide clean air and water supply. This study aims to find optimum number of green area in Jakarta. Optimization of green area will be done by using Goal Programming method. The results of this study revealed that the optimum of green area in Jakarta is 19.62% or 129,800,045 m^2. With the land costs assumptions is 2 million rupiahs per m^2, the fund should be prepared to increase the green space from 9.84% to 19.62% is 129.413 trillion rupiahs. It is hoped that the findings of the research can be used as the basis for communities and policy makers to increase green space in Jakarta.

Keywords: **optimization models, climate change, green area**

1 Introduction

Research conducted by Listyarini, *et al.* [1] stated that starting in 2012 it is predicted that there will be 1933 residents of Jakarta who have symptoms of respiratory illness caused by nitrogen oxides (NO_x), especially air pollution gases from vehicles, and the number will increase gradually. Research conducted by Warlina, *et al.* [2] stated that climate change has taken place in Jakarta evidenced by rising temperatures and rainfall. The climate change gives a significant impact on decreasing water resources and increasing the case of diseases. One of the efforts to reduce the emissions of CO_2 and to encrease the O_2 levels is by increasing the green area.

Extensive efforts to increase green areas in Jakarta requires huge funding. Some green areas in Jakarta has been changed into commercial areas. The Jakarta provincial government get source of funding from taxes and retributions as well as advertisement from that commercial areas. Eventhough Jakarta Provincial Government get funding from that commercial areas, but the provincial goverment still continues to increase the green areas since the green areas can significantly reduce air pollution. Currently, the total green areas in Jakarta is only 9.84% of the total city areas. To achieve the target of 30% of green areas based on Indonesian Law No. 26/2007, the provincial government is only able to provide 20% of green areas, where 14% comes from public and 6% from private. The target of the provincial government in 2012 is to increase 22.8 hectares (1%) of green area [3].

Given the importance of green areas to reduce the water, soil and air pollution, and considering the huge funding to increase the green area in Jakarta, it would require extensive research to determine the optimum space of green area. Optimum green area can be obtained by calculating amount of funding to be provided in order to obtain the green area needed. This study aims to find optimum space of green areas in Jakarta using Goal Programming.

2 Materials and Methods

In big cities like Jakarta increasing the population will cause in increasing industries, the need for land for housing and public activities, and transportation, which also lead to increasing in energy use. Of course, all these things will cause increasing the concentration of carbon dioxide (CO_2) in the atmosphere, that causing global warming that will be followed by climate change and ultimately lead to environmental degradation. Climate changes will have direct impacts and the derivative impacts, such as water resources are reduced, declining productivity of fisheries, declining agricultural productivities and food securities, and declining air qualities. All of these impacts would lead to disruption derivative of economic activities. The impact of climate change is attempted to diminimalized by increasing the green areas. What is the optimal space of green areas in Jakarta to minimalized the impact of climate change will be analyzed with optimization model using Goal Programming method (Figure 1).

Optimization model developed by the Goal Programming (GP) method is used to connect between the goal and constraints that are not entirely complete [4]. The purpose of the GP method is to minimize the deviation from the multi-purpose against their relative performance.

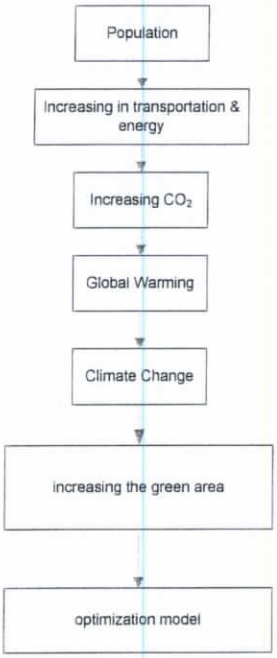

Figure 1. Framework of Research

GP formulated in the context of linear programming problems, but its principles are built through a non linear problem. According to Thompson and Thore [5] linear GP can be formulated as:

$$\sum_{i=1}^{k} a_{ij} x_j = g_i + g_i^+ - g_i^- \quad \text{.............................} \quad (1)$$

where:

a_{ij} = Number of units of input

x_j = Number of units of product

g_i = Goal or target of the variables to be achieved, for example, the target area of land used for green areas

g_i^+ = Excess performance relative to the goal, for example, the penalty for excess of CO_2 emitted

g_i^- = Performance deficit relative to the goal, for example, the penalty for lack of funds to expand the green areas

i and = integer stating the i and j goals

In this study, the equation (1) can be simplified to state a minimum amount of penalty to be acquired, as follows:

$$\text{Min}\,(qA)x + Mg^{+} + Ng^{-} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where:

qA = number of inputs
x = cost per unit of input
M = penalty cost per unit of CO_2 excess
N = the cost of losses per unit cost of the expansion of the green spaces

with restrictions:

$g^{+}.g^{-}=0$ which means that both the positive deviation should not be coincide

$x, g^{+}, g^{-} \geq 0$ which means the number of products and the second deviation should not be negative

Development of optimization models was conducted by Goal Programming, using GAMS software or General Algebraic Modeling System [6,7]. Table 1 shows the types of data used in the optimization model to analyze the optimal space of the green areas that can be used as a source of clean air and water to keep the cost of its CO_2 excess impact minimal.

The data used in this study is secondary data obtained from the CBS (Central Bureau of Statistics). Data collected is time series data in 2000-2010. The data are:

1. Total population = 8,524,152 people. It is the population of Jakarta in 2010, registered by mid-year.
2. Total of the green areas of Jakarta = 65,093,568 m^2 or 9.84% as stated by Bowo [3].
3. Sale value of land per m^2 = Rp. 2,000,000.00. It is the lowest price of the land at the price range of Jakarta declared by Nugroho [8].
4. Transportation (number of vehicles) = 11,997,519. It is number of vehicles registered in Jakarta in 2010.
5. Energy (the amount of fuel sales) = 11,661,356 tons/month. It is averaged based on CBS data in 2002-2009.
6. Average temperature and rainfall.
7. Cases of dengue fever.

The data is processed to be inputed into the GAMS software. In addition to these data, the model also used data and assumptions of previous research results, as shown in Table 1.

Table 1. Data matrix as a reference to the development of optimization model

Product	X	g_1	g_2	Exsisting	Unit
Space of green area	1	1	0	65093568	m^2
CO_2	825	0	-1	159675000	kg/day
Price		2	0,12		million rupiah

Table specification:

1. Products (X)
   Land of green area per 1 m^2 will absorb X kg of CO_2 (825 kg) per day (data calculated based on Bappenas [9]).
2. Existing:
   The existing green areas in Jakarta [3] is 9.84% or 65,093,568 m^2.
   CO_2 is the amount of CO_2 emissions released by people, vehicles, and fuel sales (data calculated based on Warlina, *et al.* [2]).
   The CO_2 emissions of the population per day are = population x (0.6 /1500) x 44/32.
   Number 44/32 is the ratio of molecular weight (Mw) of CO_2 to O_2 molecular weight.
   The average emissions of hydrocarbons (HC) from vehicles = HC (kg/yr)/ number of vehicles = 58.402.
   CO_2 emissions of the vehicle = 44/16 x HC emissions. It is assumed that an average fuel has 8 chain, the fuel is converted to CO_2 = (1 mol fuel = 114 g, 1 mol CO_2 = 44; the average of specific density of fossil fuel = 0.8). Weight of fossil fuel = fuel sales x 0.8.
   CO_2 emissions from fossil fuel = weight of fossil fuel x 44/114.
   Total CO_2 emissions = CO_2 emissions of the from population + CO_2 emissions of the from vehicles + CO_2 emissions from fossil fuel = 159,675,000 kg.
3. Price:
   It is stated the price for each additional unit space of green area, and the abatemen cost from an excess of CO_2 per tonne.
   - g_1: Price of land per m^2 (Rp 2 million) is determined based on a relatively low price [8].
   - g_2: Cost abatemen due to excess CO_2 is assumed as a result of air pollution. The treatment cost is Rp. 0.12 million or Rp.120.000 per day (it is cost of treatment without hospitalization based on Fatmawati [10]).

Based on the data in Table 1 the mathematical equations was developed to find the maximum space of green area by the formula (1) as follows:

Max amount of CO_2 emissions = CO_2 + surplus emission targets – green area deficit .... (3)

The maximum of CO_2 total emission from the equation (3) will give a penalty (cost abatemen pollutants or health expenses) of at least derived from the formula (2), namely:

Min Penalty = Min (green area) * Price of land per m^2 + penalty fee caused by the excess CO_2 emissions + deficit of green area .... (4)

The mathematical equations developed and values in Table 1 matrix is processed to obtain the optimal values of the space green area, with CO_2 emissions below the target by using the software GAMS. This sofware can be downloaded freely from http://www.gams.com. GAMS is a programming language, so it is necessary to write the program as an input file, by entering the values from the data matrix (Table 1) along with mathematical equations [6, 7].

3 Results and Discussion

In this study, CO_2 emissions in Jakarta are assumed come from people, vehicles and fuel combustion, the total value was 159,675,000 kg/day. In order to absorb CO2 emissions it is necessary to have plant that has green leaves that will absorb CO_2 in the process of photosynthesis. Green area is widely used to indicate how many plants are located in Jakarta. Bappenas [9] declared green area per hectare can produce 0.6 tons of oxygen (O_2), which is the result of the process of photosynthesis CO_2 and H_2O absorption by their green leaves. With converting the weight of O_2 to CO_2 by reaction of photosynthesis it can be obtained 825 kg of CO_2 per day which can be absorbed by per m^2 green space.

CO_2 emissions resulting from human activities in Jakarta cannot be absorbed totally by the plants that are grown in Jakarta, it can be evaluate from the increasing of concentration of CO_2 in the ambient air and the average of temperature. This data obtained from the time series data from Central Bureau of Statistics (CBS), represent the average temperature in Jakarta in 2000 was 27.1 °C and in 2010 increase to 27.95 °C. In addition, the CO_2 concentration in the air will not only increase the temperature, but it will also cause climate change and lead to various diseases.

Climate changes in Jakarta could cause increasing average rainfall from year to year, 158.1 mm in 2000 increased steadily up to 240.45 in 2010. While the increase in cases of disease can be detected from dengue fever cases. It is recorded in 2000 there was 8729 cases fluctuated from year to year, until the year 2010 it reached 21,151 cases. According to Junaedy [11] the relationship between increasing air temperature with cases of the diseases, the study stated that rising temperatures will cause shorter incubation period of the mosquito that caused spread of the various diseases. Consequently, the diseases transmitted by mosquitoes will go faster. The spread of the diseases by mosquitoes, such as dengue, diarrhea, malaria and leptospirosis, is generally found in tropics region. This study is not specified the name of the diseases one-by-one, but it is assumed that the cost of the health treatment was Rp.120.000,00 per day [10].

All figures were generated with the GAMS software and processed in the input file. The GAMS processing results in the form of the output file can be seen in the Appendix. GAMS processing results stated that the optimum green area required is 129,800,045 m^2, or 19.62% of the Jakarta total area. The optimum of green area is calculated based on the cost to be incurred to expand green area is Rp. 2 million per m^2 and the abatement costs to be incurred if the CO_2 emissions that cannot be absorbed by the green area caused the diseases. To increase the green area from the current 9.84% to 19.62% required Rp.129.413 trillion of funding.

The Government of Jakarta has not owned this huge of funding. Therefore, the Government target was only 13.94% of the green area [3]. This target was still far below of the space green area specified in Law No. 26 Year 2007, which is 30%. Currently, the total of green area owned by Government of Jakarta is 65,093,568 m^2 or 9.84% of its territory, the government of Jakarta intended to increase the target of green area to 95,450,000 m^2 or 13.94%. Thus, Government of Jakarta has to increase the space of green area to 35,913,200 m^2. In the mean time, in 2012 the government of Jakarta will expand the green area covering 22.8 hectares [3]. If each year Jakarta can only expand approximately 22.8 hectares of green area, then the target to acquire 13.94% of the space green areas will be achieved within 15 years. Within 15 years the people have to pay for medical expenses incurred as a result of the high concentration of CO_2 in the air.

The results of this study stated that the space of green area in Jakarta will be optimum if covering 19.62% of the total area, this figure is not too far from the long-term target of the government of Jakarta. Because the Government of Jakarta was not likely to have space of green area 30%, as the demands of Law Number 26 of 2007. The Jakarta Governor declaredthat the city government is only able to provide 20% of space of green area. The number is split 14% of the public (13.94% Government) and 6% private [3]. This means that the expansion of Jakarta green area up about 20% of the total area is not fully the responsibility of the Jakarta Government, but also the responsibility of all citizens to improve their health that disturbed due to the high concentration of CO_2 in the air.

4 Conclusions

Development of optimization models with the goal programming method in this study produces the optimal space of green area in Jakarta is 129,800,045 m^2 (19.62%) of the total area. This result is close to the long-term target of the Jakarta Government to have at least 20% space of green area. The expansion space of green area from the existing (9.84%), is not entirely the responsibility of the Jakarta Government, but also the responsibility of all citizens. The awareness to expand green area will be more easily obtained, if the community realizes the importance of green area for all of us. Moreover, if people are given the information that damages must be paid by the entire community in the form of healthcare costs, due to the high concentration of CO_2 in the air that cannot be absorbed by the current space of green area.

This study takes into account health costs to society due to high concentration of CO_2 in the air, other than disease, it can also contribute to climate change results in higher rainfall which affects flooding. Further research to count losses due to flooding and other negative effects of the lack of green area needs to be done, as the material to sensitize the public and policy makers on the importance of green area.

In this study, it is assumed that the ability of green area to absorb CO_2 directly proportional to the space of green area. In fact the ability of each type of plant is different. It needs further research on what types of plants absorb the most of CO_2, so that its concentration can be minimized. The results of this study can be used to make people aware that people can grow plant in every arable land, even in a pot.

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