Optimization model for predicting green areas in Jakarta to minimize impacts of climate change

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Abstract

Some studies about climate change in Jakarta have 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 areas. Under Indonesian Law No. 26/2007 the proportion of ideal green area in big cities like Jakarta is 30% of the total city areas; unfortunately at this time the green area in Jakarta is only 9.84%. The effort to increase green areas in Jakarta requires huge funds, since the price of land in Jakarta is very expensive. On the other hand, green space is a critical requirement to provide clean air and water supply. This study aims to find an optimum number of green areas in Jakarta. Optimization of green areas will be done using the goal programming method. The results of this study revealed that the optimum amount of green area in Jakarta is 19.62% or 129,800,045 m^2. With the land costs assumptions at 2 million rupiahs per m^2, the fund should be prepared to increase the green space from 9.84% to 19.62% at 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

WIT Transactions on Ecology and The Environment, Vol 191, © 2014 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/SC140261

by rising temperatures and rainfall. The climate change makes a significant impact on decreasing water resources and increases the cases of diseases. One of the efforts to reduce the emissions of CO_2 and to increase the O_2 levels is by increasing the green areas.

Extensive efforts to increase green areas in Jakarta requires huge funding. Some green areas in Jakarta have been changed into commercial areas. The Jakarta provincial government gets funding from taxes and retributions as well as advertising from those commercial areas. Even though Jakarta Provincial Government get funding from those commercial areas, the provincial government 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 sources. The target of the provincial government in 2012 is to increase 22.8 hectares (1%) of green areas [3].

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

2 Materials and methods

In big cities like Jakarta increasing the population will cause an increase in industries, the need for land for housing and public activities, and transportation, which also leads to increasing energy use. Of course, all these things will cause an increase in concentrations 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 reduced water resources, 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 be minimalized by increasing the green areas. The optimal space of green areas in Jakarta to minimalize the impact of climate change will be analyzed with an optimization model using the goal programming method (Figure 1).

An 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.

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:

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

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.

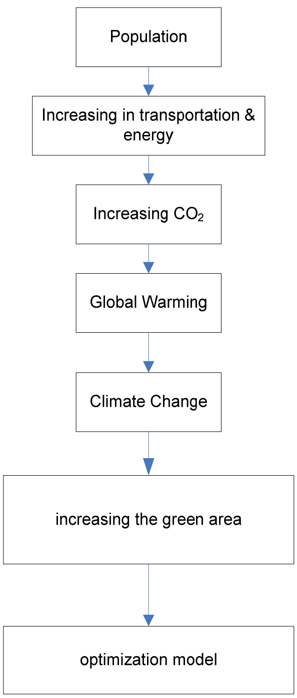

Figure 1: Framework of research.

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

WIT Transactions on Ecology and The Environment, Vol 191, © 2014 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)

$$\mathrm{Min}\,(qA)x + Mg^{+} + Ng^{-} \tag{2}$$

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 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 the 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).

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

$$\begin{gathered}\text{Max amount of } CO_2 \text{ emissions} = CO_2 \\ + \text{ surplus emission targets} - \text{green area deficit}\end{gathered} \tag{3}$$

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

$$\begin{gathered}\text{Min Penalty} = \text{Min (green area)} * \text{Price of land per } m^2 + \text{penalty fee caused} \\ \text{by the excess } CO_2 \text{ emissions} + \text{deficit of green area}\end{gathered} \tag{4}$$

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

Product	X	g^{-}_{1}	g^{-}_{2}	Existing	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]).

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 to come from people, vehicles and fuel combustion. The total value was 159,675,000 kg/day. In order to absorb CO_2 emissions it is necessary to have plants that have green leaves that will absorb CO_2 in the process of photosynthesis. Green areas are widely used to indicate how many plants are located in Jakarta. Bappenas [9] declared that a 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. By converting the weight of O_2 to CO_2 by reaction of photosynthesis, 825 kg of CO_2 per day can be obtained 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 evaluated from the increase of concentrations of CO_2 in the ambient air and the average temperature. This data obtained from the time series data from Central Bureau of Statistics (CBS), represents that the average temperature in Jakarta in 2000 was 27.1°C and in 2010 it increased 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 that in 2000 there were 8,729 cases fluctuating from year to year, until the year 2010 when it reached 21,151 cases. According to Junaedy [11] the relationship between increasing air temperature and cases of the diseases; the study stated that rising temperatures will cause a shorter incubation period of the mosquito that caused a 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 tropical regions. This study has not specified the name of the diseases one-by-one, but it is assumed that the cost of the health treatment would be 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 green area is calculated based on the cost to be incurred to expand green areas, being 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 areas from the current 9.84% to 19.62% required Rp.129.413 trillion of funding.

The Government of Jakarta does not have this huge amount of funding. Therefore, the Government target was only 13.94% of the green area [3]. This target was still far below the green area space specified in Law No. 26 of the 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 green area to 95,450,000 m^2 or 13.94%. Thus, the

Government of Jakarta has to increase the space of green area to 35,913,200 m^2. In the meantime, in 2012 the government of Jakarta would have to expand the green area covering by 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 will 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 and 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 30% of green area space, according to the demands of Law Number 26 of 2007, the Jakarta Governor declared that the city government is only able to provide 20% of green area space. The number is split 14% of the public (13.94% Government) and 6% private [3]. This means that with the expansion of Jakarta green area, about 20% of the total area is not fully the responsibility of the Jakarta Government, but is also the responsibility of all citizens to improve their health which has been 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 shows that 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, namely, 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 is also the responsibility of all citizens. Awareness to expand green areas will be more easily achieved if the community realizes the importance of green areas for us all. 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 the high concentration of CO_2 in the air; other than disease, it can also contribute to climate change resulting 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 a green area to absorb CO_2 is directly proportional to the space of green area. In fact, the ability of each type of plant is different. Further research is needed on what types of plants absorb the most CO_2, so that its concentration can be minimized. The results of this study can be used to make people aware that they can grow plants in every arable land; even in a pot.

Appendix

```
GAMS Rev 138  MS Windows                    06/09/12 07:44:05 Page 1
General Algebraic Modeling System
Compilation
* Green Area Model: The Jakarta Province should have an area of green space 30% (198.456.000m2),
* now the area of green space in Jakarta only 9,84% ( 65.093.568 m2)
* the green space expansion requires substantial funding, if green area is not expanded
* the CO2 concentration in the Jakarta air will increase and causes some illness
    and the cost of care (Rp. 120000/day)
* Land prices Rp.2.000.000/m2)

SETS
  I      goals / RTH,CO2/;

PARAMETERS
  MPENALTY(I)   penalty or loss if the green area produced less than a target
              /RTH        0
               CO2        0.12/
  NPENALTY(I)   costs that must be incurred if the resulting of the green space on target
              /RTH        2
               CO2        0/
  B(I)          output per 1 m2 RTH to absorb CO2
              /RTH        1
               CO2        825/
  GOAL(I)       target of green area to be obtained and the precise amount of CO2
              /RTH        65093568
               CO2        159675000/ ;

VARIABLES
  COSTS         total penalty and cost

POSITIVE VARIABLES
  X             green area result
  GPLUS(I)      excess relative to the goals
  GMINUS(I)     deficit relative to the goals;

EQUATIONS
  OBJECTIVE     function to calculate the total penalties and costs
  DEFGOAL(I)    definitions of each goal I;

OBJECTIVE..     COSTS =E= SUM(I,MPENALTY(I)*GPLUS(I)+
```

```
                      NPENALTY(I)*GMINUS(I));
DEFGOAL(I)..     B(I)*X-GPLUS(I)+GMINUS(I) =E= GOAL(I);

MODEL RTH /ALL/;
SOLVE RTH USING LP MINIMIZING COSTS;
```

```
COMPILATION TIME     =        0.000 SECONDS     3.2 Mb   WIN213-138 Feb
03, 2004
GAMS Rev 138  MS Windows                          06/09/12 07:44:05 Page 2
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Equation Listing    SOLVE RTH Using LP From line 41
---- OBJECTIVE  =E=  function to calculate the total penalties and costs
OBJECTIVE..  COSTS - 0.12*GPLUS(CO2) - 2*GMINUS(RTH) =E= 0 ; (LHS
= 0)
---- DEFGOAL  =E=  definitions of each goal I
DEFGOAL(RTH)..  X - GPLUS(RTH) + GMINUS(RTH) =E= 65093568 ;
    (LHS = 0, INFES = 65093568 ***)
DEFGOAL(CO2)..  825*X - GPLUS(CO2) + GMINUS(CO2) =E= 159675000 ;
    (LHS = 0, INFES = 159675000 ***)
GAMS Rev 138  MS Windows                          06/09/12 07:44:05 Page 3
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Column Listing      SOLVE RTH Using LP From line 41
---- COSTS  total penalty and cost
COSTS
          (.LO, .L, .UP = -INF, 0, +INF)
     1      OBJECTIVE
---- X  green area result
X
          (.LO, .L, .UP = 0, 0, +INF)
     1      DEFGOAL(RTH)
   825       DEFGOAL(CO2)
---- GPLUS  excess relative to the goals
GPLUS(RTH)
          (.LO, .L, .UP = 0, 0, +INF)
    -1      DEFGOAL(RTH)
GPLUS(CO2)
          (.LO, .L, .UP = 0, 0, +INF)
    -0.12    OBJECTIVE
    -1      DEFGOAL(CO2)
---- GMINUS  deficit relative to the goals
GMINUS(RTH)
          (.LO, .L, .UP = 0, 0, +INF)
    -2      OBJECTIVE
     1      DEFGOAL(RTH)
GMINUS(CO2)
          (.LO, .L, .UP = 0, 0, +INF)
```

```
      1      DEFGOAL(CO2)
GAMS Rev 138  MS Windows                        06/09/12 07:44:05 Page 4
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Model Statistics    SOLVE RTH Using LP From line 41
MODEL STATISTICS
BLOCKS OF EQUATIONS      2    SINGLE EQUATIONS       3
BLOCKS OF VARIABLES      4    SINGLE VARIABLES       6
NON ZERO ELEMENTS        9
GENERATION TIME      =       0.016 SECONDS     3.9 Mb   WIN213-138 Feb
03, 2004
EXECUTION TIME       =       0.016 SECONDS    3.9 Mb  WIN213-138 Feb 03,
2004
GAMS Rev 138  MS Windows                        06/09/12 07:44:05 Page 5
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Solution Report     SOLVE RTH Using LP From line 41
           S O L V E     S U M M A R Y
    MODEL   RTH           OBJECTIVE  COSTS
    TYPE    LP            DIRECTION  MINIMIZE
    SOLVER  CPLEX         FROM LINE  41
**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      1 OPTIMAL
**** OBJECTIVE VALUE        129800045.0909
 RESOURCE USAGE, LIMIT         0.000      1000.000
 ITERATION COUNT, LIMIT        0          10000
GAMS/Cplex    Jan 19, 2004 WIN.CP.NA 21.3 025.027.041.VIS For Cplex 9.0
Cplex 9.0.0, GAMS Link 25
Optimal solution found.
Objective :   129800045.090909
                 LOWER     LEVEL     UPPER    MARGINAL
---- EQU OBJECTIVE       .         .         .         1.000
  OBJECTIVE  function to calculate the total penalties and costs
---- EQU DEFGOAL  definitions of each goal I
     LOWER     LEVEL     UPPER    MARGINAL
RTH 6.5094E+7 6.5094E+7 6.5094E+7     2.000
CO2 1.5968E+8 1.5968E+8 1.5968E+8    -0.002
      LOWER     LEVEL     UPPER    MARGINAL
---- VAR COSTS         -INF  1.2980E+8     +INF       .
---- VAR X             .    1.9355E+5     +INF       .
  COSTS  total penalty and cost
  X  green area result
---- VAR GPLUS  excess relative to the goals
     LOWER     LEVEL     UPPER    MARGINAL
RTH      .         .        +INF      2.000
CO2      .         .        +INF      0.118
---- VAR GMINUS  deficit relative to the goals
     LOWER     LEVEL     UPPER    MARGINAL
```

```
RTH     .  6.4900E+7    +INF      .
CO2     .       .       +INF    0.002
**** REPORT SUMMARY :       0     NONOPT
                        0 INFEASIBLE
                        0  UNBOUNDED
EXECUTION TIME      =       0.000 SECONDS    2.2 Mb  WIN213-138 Feb 03, 2004
USER: GAMS Development Corporation, Washington, DC   G871201:0000CA-ANY
     Free Demo,  202-342-0180,  sales@gams.com,  www.gams.com   DC9999
```

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