Dynamic Model to Reduce the Impact of Climate Change on the Environment and the Economy

Lina Warlina and Sri Listyarini

Abstract—Climate change is a global phenomenon will have a great impact for human life, such as the impact on the environment and the economy. To conduct research on climate change experimentally rather difficult to do, because it takes a long time and substantial funds, so one of the approach is to create a model. The purpose of this study was to develop a model that can be replicated for the response to climate change impacts on environmental and economic aspects. The method used in this research is a dynamic system model to simulate the impact of climate change. The results showed a reduction in the number of vehicles and fuel sold will have an impact on the reduction of CO₂ emissions, so it will reduce the incidence of diarrhea and dengue cases and automatically will reduce economic losses.

Index Terms—Climate change, environment, dynamic system.

I. INTRODUCTION

The development of technology and industry can impact either positive or negative for human life. The positive impact is expected to increase human welfare, but the negative effects can degrade the quality of human life. In addition, the negative impact caused disharmony and environmental balance. The development of technology and the industry has a significant role in the implementation of the development. The increase in population in many respects also encourages industrialization. As a consequence, the amount of raw materials and industrial waste is increasing, both in terms of quality and quantity. Of course, this will have a negative impact on the environment, such as pollution or climate change.

In Indonesia, the impact of extreme weather can be seen from the incompatibility of the changing seasons in various regions. Some regions suffer from drought, while other areas were flooded. This makes a lot of negative effects, especially for farmers who can no longer determine the harvest season so it makes a lot of crop failure, and also impacts on health and the environment. Based on research conducted by Warlina et al. [1], also stated that there has been a climate change in Jakarta.

According to Ellis and Kasyanov (2008) [2], environmental issues are considered quite important is the reduction of water supply for 55% of the world's population, the loss of around 11,000 species of plants and animals that cause a reduction in 30% of the world's biodiversity in the middle of this century, and increasing emissions of carbon dioxide (CO₂) that cause global climate change. Of the three proposed environmental issues, global climate change is a very important role, as the climate changes affect the two other global environmental problems. The mechanism is climate change affecting environmental factors such as air and soil quality, depletion of the ozone layer, reduction in water quality and quantity, ecosystems function loss and land degradation that ultimately these factors will affect human health. Of course, climate change will also affect the world economy.

To conduct research on climate change experimentally rather difficult to do, because it takes a long time and substantial funds, so the approach is to create a model. Based on this background, this research is done by using a model of system dynamics to analyze the impact of climate change on the environment and the economy. This study is a continuation of the research that has been done [1] by adding variables that have not been accounted for in previous research, namely green open space and industry that is represented with the fuel sales.

The purpose of this study was to develop a model of a dynamic system that can be used as a reference in the response to climate change impacts on environmental and economic aspects. Environmental aspects of this research is the impact on CO₂ emissions is also related to temperature and rainfall, while the economic aspect is the loss of material due to illness cases caused by CO₂ emissions.

II. METHODS AND MATERIALS

This study uses a dynamic system approach to analyze the impact of climate change on the environment and the economy, while to analyze the relationship between variables used regression analysis. Software used for regression analysis is MINITAB, and for a dynamic system is VENSIM. Data was used in this research is secondary data that was collected as a time series from 2000-2013.

Dynamic system used to analyze the behavior change aligned with changes in the timing of a complex system [3]. In this study, changes in environmental and economic consequences of climate change. Through a dynamic system can be seen changes in the system primarily to assess the effectiveness of planning policy. Modeling and simulation models as part of a method of dynamic systems also implement several phases of activity, namely making the concept, modeling, simulation models, model validation, as well as policy analysis [4].

III. ASSUMPTION

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The assumptions used to analyze the impact of CO₂ emissions on the environment and sources of CO₂, based on previous research conducted by Warlina et al. (2009). All the equations result of Minitab is used in a dynamic system for relationships between variables. Some assumptions are:

- CO₂ emissions from residential
- CO₂ emissions from vehicles
- CO₂ emissions from fuel

According to Bappenas (2008) [5], 1 hectare of green space is able to produce 0.6 tons of oxygen. The amount to be consumed 1,500 residents per day, reduce the temperature of 5-8°Celsius, reduce noise 25-80 percent, and 75-80 percent absorbs pollutant gases. Thus the calculation of the CO₂ emissions of the population is the number of population \( x \) \((0.6/1500) \times 6 \times 365\).

![Image](image_url)

Fig. 1. The SFD of climate change impact on economic and environmental.

To run the dynamic model, the relationship of the variable should be stated in the equation that come from the relationship between variables through regression analysis. Some relationship of each of these variables is as follows:

- \( \text{Temperature} = 26.723 + 0.000000 \times \text{Total Emission of CO}_2 \)
- \( \text{Dengue cases} = 11216 + 89 \times \text{Total emission of CO}_2 \)
- \( \text{Rainfall} = 1945 + 0.000009 \times \text{Total Emission of CO}_2 \)
- \( \text{Dengue cases} = 59519 + 3.86 \times \text{rainfall} - 1927 \times \text{Temperature} \)
- \( \text{Water sold} = -461634871 + 5938 \times \text{rainfall} + 26582237 \times \text{Temperature} \)
- \( \text{Dengue cases} = 1034919 - 0.00248 \times \text{water sold} \)
- \( \text{Total Emission of CO}_2 = -13143676 + 3.728 \times \text{populations} \)
- \( \text{Total Emission of CO}_2 = 6254506 + 1.263 \times \text{numbers of Vehicles} \)
- \( \text{Total Emission of CO}_2 = 5691281 + 407697 \times \text{fuels sales} \)
- \( \text{Total Emission of CO}_2 = 39614493 - 0.973 \times \text{the area of green open space} \)
- \( \text{Total Emission of CO}_2 = 0.000000 + 0.1606 \times \text{numbers of vehicles} + 308772 \times \text{fuels sales} - 0.005684 \times \text{the area of green open space} + 0.8760 \times \text{populations} \)

It appears that almost all of the variables have a positive impact on the CO₂ emission increases unless extensive green open space. The higher the green open space, it will further reduce the CO₂ emissions. It is possible, because one of the functions of green space that can absorb the CO₂.

Based on the analysis of the regression equations, it appears that the effect of CO₂ emissions on temperature is
very small, so it does not appear in the equation. Based on
IPCC research (The Working Group I contribution to the
IPCC’s Fifth Assessment Report) considers new evidence of
climate change based on many independent scientific
analyses from observations of the climate system,
paleoclimate archives, theoretical studies of climate
processes and simulations using climate models stated that
the globally averaged combined land and ocean surface
temperature data as calculated by a linear trend, show a
warming of 0.85 [0.65 to 1.06] °C, over the period 1880 to
2012 [9]. Thus the effect of CO₂ emissions in 14 years in this
study did not look significantly influence the temperature
increase. Another case with the effects of CO₂ emissions on
rainfall, although small, but seemed to influence on rainfall.

When analyzed individually the effect of temperature,
rainfall and the dengue cases, it appears that the two variables
are significant. However, when analyzed simultaneously
influence, the influence of rainfall had a positive effect, while
the effect of temperature has a negative impact. That is, the
rainfall impact is greater than the temperature of the dengue
cases.

For a relationship to water sold by rainfall, it appears that
when rainfall is high, then the clean water sold is reduced.
This is consistent with the fact that when rainfall is high, they
do not need to buy water. They can collect rainwater for
various needs. Another case with the effect of temperature on
water sold, the higher the temperature, the water sold also
rose.

Relations clean water sold in cases of diarrhea has negative
relationships. When water sold higher, then it will be less
cases of diarrhea. This is in accordance with reality,
increased use of clean water, the environment becomes clean,
cases of diarrheal disease will be less.

A. The Results of Dynamic Systems Model

Until 2025, the Jakarta population growth will continue
to rise to approximately 13 million if they do not do anything
policies (do nothing), as shown in Fig. 2. In addition, there is
also an increase in total CO₂ emissions coming from the
number of vehicles, people, sales of fuel and green open
space. The graph in fairly sharp increase in CO₂ emissions
until 2025.

On the other hand, CO₂ emissions also have an impact on
the number of dengue cases and the amount of water
consumed. The increased rainfall and temperatures will result
in an increase in dengue cases. Until 2025, dengue cases will
increase to approximately 125,000 people when no specific
policies. Similarly to the case of diarrheal diseases. Until
2025, cases of diarrheal diseases are also increasing. The
number of cases of diarrhea was higher than the dengue
disease.

Unlike the other variables that increase steadily, clean
water used variable to decrease until 2025. This is
understandable, because of the increasing water supplies are
depleted, so that clean water sold is also diminishing (Fig. 2).
The entire increase in the variables in this study, of course,
would impact on the economy. The value of Indonesian
public life or the Value of Statistical Life (VOSL) is based on
research by Susandi (2004)[10] in the amount of US
$ 144,000 or approximately Rp.1,944,000,000,- (rate of Rp.
13,500,-). In addition, health care costs are not only diarrhea
dengue fever are calculated based on the cost of
treatment and care, but also the losses caused due to people
unable to perform his job during an illness related to the
wages these patients. The economic losses caused two cases
of the disease as in Fig. 2. If there is no policy to reduce
emissions, the economic loss will reach about Rp.1.2 trillion
in 2025. This value is quite high, so we need a policy to
reduce this value.

B. Results of Simulation Model

Simulations carried out until 2025 at the rate of population
growth, a reduction in fuel, reduction in the number of
vehicles and increase green open space. Impacts are analyzed,
that is to CO₂ emissions, cases of dengue, diarrhea and
economic losses. Analysis of simulated data is done by value
in 2020 and 2025. It is based on a binding international
agreement as a shared commitment to reducing the world’s
greenhouse gas emissions were being applied after 2020. The
meeting also resulted in the Paris Agreement, which
mentions countries of the world committed to keeping the
threshold limit global temperature increase to below 2°C and
trying to suppress until 1.5°C [11]. Therefore, the analysis
conducted in 2020 and the next 5 years, that is 2025.

1) Simulation of changes in the rate of population growth

Based on population data from 2000-2013, the population
growth rate is 2.04%. Although this figure is not so high, but
the government should be able to anticipate that population
growth not to to rise again. This can be done with the
ratification of policy of Family Planning Program, so that
population growth can be suppressed. Assuming the
existence of policy of family planning program which will
suppress the population growth rate of 1.5% and 1.75%, this
policy will have an impact also on CO₂ emissions and the

Fig. 2. Result of a dynamic system.
impact on other variables. The simulation results, changes in population growth as shown in Fig. 3.

Based on the resulting graph of the simulation, it appears that the reduction of population growth rate of 1.5% and 1.75% has little effect on CO$_2$ emissions, cases of dengue fever, diarrhea and economic losses. When calculated based on the value, the percentage of reduction in Table I.

When simulation was done decline in the population growth rate of 1.5%, then by 2025 there will be a reduction in CO$_2$ emissions significant, that is 7.66%. Likewise for other variables, a reduction varied.

2) Simulation of reduction in fuel sales

Simulation on fuel sales did with the reduction of fuel sales by 5%, 10% and 30%. The reduction had a significant impact on CO$_2$ emissions, the incidence of diarrhea, dengue cases and economic loss.

Based on simulation, fuel sales reduction of 30% is a very significant reduction. This can be seen in Table II.

The result of simulation can be described as a picture in Fig. 4.
TABLE I: SIMULATION RESULTS OF THE IMPACT OF POPULATION GROWTH

<table>
<thead>
<tr>
<th>Growth (%)</th>
<th>Reduced CO₂ emission (%)</th>
<th>Reduced economic losses (%)</th>
<th>Reduced diarrhea cases (%)</th>
<th>Reduced dengue cases (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.75</td>
<td>3.44</td>
<td>4.22</td>
<td>1.04</td>
<td>1.13</td>
</tr>
<tr>
<td>1.5</td>
<td>6.27</td>
<td>7.66</td>
<td>1.95</td>
<td>2.53</td>
</tr>
</tbody>
</table>

TABLE II: SIMULATION RESULTS OF THE IMPACT OF REDUCTION IN FUEL SALES

<table>
<thead>
<tr>
<th>Reduction in fuel sales (%)</th>
<th>Reduced CO₂ emission (%)</th>
<th>Reduced economic losses (%)</th>
<th>Reduced diarrhea cases (%)</th>
<th>Reduced dengue cases (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5.00</td>
<td>5.00</td>
<td>5.01</td>
<td>5.00</td>
</tr>
<tr>
<td>30</td>
<td>29.9</td>
<td>29.98</td>
<td>29.98</td>
<td>29.98</td>
</tr>
</tbody>
</table>

TABLE III: SIMULATION RESULTS OF THE IMPACT OF REDUCTION IN NUMBER OF VEHICLES

<table>
<thead>
<tr>
<th>Reduced vehicles (%)</th>
<th>Reduced CO₂ emission (%)</th>
<th>Reduced economic losses (%)</th>
<th>Reduced diarrhea cases (%)</th>
<th>Reduced dengue cases (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.37</td>
<td>0.36</td>
<td>0.25</td>
<td>0.26</td>
</tr>
<tr>
<td>10</td>
<td>0.75</td>
<td>0.72</td>
<td>0.51</td>
<td>0.52</td>
</tr>
<tr>
<td>25</td>
<td>1.88</td>
<td>1.80</td>
<td>1.27</td>
<td>1.30</td>
</tr>
</tbody>
</table>

Based on Table II, a reduction in fuel sales will have an impact similar to the reduction of other variables. This is causing the influence of other variables little effect on CO₂ emissions. It can be seen from the equation, namely the relationship of CO₂ emissions with fuel sales, the number of vehicles and extensive green open space. Thus, policies related to the reduction of fuel urgently need to be followed, because it will greatly affect other impacts.

3) Simulated reduction in the number of vehicles

Simulated reduction of the number of vehicles taken to a reduction of 5%, 10% and 25%. Based on the resulting graph in Fig. 5, the reduction in the number of vehicles by 5%, 10% and 25% is very little difference, so the graph like a pile. When analyzed based on the data, the reduction actually occurs, but very small. This can be seen in Table III. Reduction in the number of vehicles by 25% gives a significant impact even though it still looks a little influence, is still below 2%. Thus, the policy of reducing the number of vehicles can be applied to a substantial reduction in order to look the effect significantly. Reduction in the number of vehicles is expected to occur quite large if public transportation is provided by the government of Jakarta has been perceived safety and convenience. A Jakarta government program that will provide a fast train or MRT (Mass Rapid Tranportation) as one tool public transportation in Jakarta is expected to reduce the number of private vehicles is quite significant and ultimately overcome traffic congestion and reduce CO₂ emissions.

4) Simulation addition of green open spaces

Increase green open space simulation was done by 2 times, 3 times and 100 times. Based on simulation results in Fig. 6, the addition of green space area is almost no effect.

Likewise, when the data were analyzed based on the
simulation results, there is little difference, as in Table IV.

![Graph](image)

Table IV summarizes the addition of green open space of 100 times or 10,000% will have an impact though it is still quite significant. Additions spacious green open space has influenced smallest to CO$_2$ emissions. It is also possible, because in reality, the current extensive green space in Jakarta is still around 9.84% [12], so in order to reduce CO$_2$ emissions, should be done extensive addition of green open space is quite high. Meanwhile, Indonesia has already had the regulation in green areas that is Indonesian Law No. 26/2007, which stated that the ideal green area in big cities like Jakarta is 30% of the total city areas [13].

![Graph](image)

**V. CONCLUSIONS AND RECOMMENDATIONS**

The impact of climate change on illness and economic losses can be demonstrated by using a dynamical system. Through simulations using this system can predict the impact of climate change for several years to come.

The smaller the population growth rate, the greater the reduction of CO$_2$. Similarly to the economic loss, the smaller the rate of population growth, the reduction of the greater economic loss. In addition, reduction in the number of vehicles and fuel sales will have an impact on the reduction of CO$_2$ emissions, so it will reduce the cases of diarrhea and dengue cases and automatically will reduce economic losses. Also, the addition of green open space should be high enough when it will have an impact on the reduction of CO$_2$ emissions.

For further research, CO$_2$ emissions can be calculated by adding another variable that has not been included in this study, for example, the industry in more details.

**REFERENCES**


[13] UNDP-UNEP, “Global assessment of the potential for achieving the MDGs in the context of climate change.”

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