Source of Carbon Dioxide Emissions Equivalent to Plant-Based Control Concept with Dynamic System in Prabumulih City, South Sumatra Province

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Abstract. Emissions of carbon dioxide equivalent (CO$_2$eq) will continue to increase along with human activities that continuously carry out land conversion activities, increased use of vehicles, increased waste, and other activities. This study aims to analyze the factors causing an increase in carbon dioxide emissions in urban areas and plant-based control using causal loops with a dynamic systems approach. Through the analysis method using the causal loop, then determined the cause and effect relationship of each CO$_2$eq emission variable and its control efforts in Prabumulih City. The results of this study describe the causal loop relationship, both positive and negative relationships between variables from urban CO$_2$eq emission sources and emission control by optimizing plant species as an absorber of CO$_2$eq emissions.

1. Introduction

The main cause of global warming is an increase in concentrations of various atmospheric greenhouse gases, which include carbon dioxide (CO$_2$), methane (CH$_4$), nitrous oxide (NO), and chlorofluorocarbons (CFCs). Increasing the concentration of greenhouse gas allows the atmosphere to absorb more thermal radiation (high wavelength) from sunlight, slowing or preventing heat loss to space, resulting in higher surface temperatures [1]. GHG is a gas contained in the atmosphere that absorbs and re-emits infrared radiation. The side effect of accumulation greenhouse gases can cause extreme climate change, affecting land productivity [2].

Fossil fuels became known during the first industrial revolution and are still used today on a large scale, where excessive consumption of fossil energy can lead to large-scale carbon dioxide (CO$_2$) emissions. It is known that CO$_2$ is the root cause of environmental problems such as global warming, rising sea levels, and often causes extreme weather [3,4]. Fossil energy contains relatively many carbon element compounds. When carbon is burned, it produces CO$_2$ gas, spreading into the atmosphere [5]. According to the UNFCCC in 2016, Indonesia's First Biennial Update Report (BUR) reported that Indonesia's total GHG emissions in 2012 were estimated to reach 1,454 million metric tons of carbon dioxide equivalent MtCO$_2$e originating from the energy, industrial sectors, waste, and agriculture [6]. The sectors contributing the most to GHG emissions were land-use change and peat, which amounted to 83% of total GHG emissions, where the land change sector was around 48%. The energy sector was about 35% of total GHG emissions. It is feared that in the coming year's GHG emissions will continue to increase [7].
The Government of Indonesia set an emissions reduction target with adaptation to low carbon as a commitment to reduce greenhouse gas emissions in 2010. The committee Indonesia targeted reducing greenhouse gases with a business-as-usual (BAU) scenario of 26% by 2020. In the sixth year, Indonesia submitted its Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC) though committing by 2030 to decrease greenhouse gas emissions by using 29% the voluntary business-as-usual (BAU) scenario and reduce by 41% if there is international assistance in terms of both technology and finance.

The committee's follow-up on greenhouse gas estimation, poured by the Indonesian government into a plan of action on greenhouse gas emissions (RAN-GHG) containing frameworks in the form of policies and guidelines for central government, local governments, stakeholders, and businesses in the period 2010-2020. The plan is outlined in President Regulation No. 61 of 2011 on the National Action Plan on Reducing Greenhouse Gas Emissions (RAN-GHG), which requires each region to draw up a Regional Action Plan to Reduce Greenhouse Gas Emissions (RAD-GHG). The GHG emissions reduction plan examines the source of emissions coming from the agricultural, forestry and peatland sectors, energy sector, transportation sector, industrial sector and waste sector.

Prabumulih City is one of the cities in South Sumatra Province, located at the position of 3°-4° S and 104°-105° E. According to the Prabumulih City Statistics Agency (2020), the population in Prabumulih City continues to increase every year. In 2017 the population of Prabumulih City was 182,128 people and grew to 184,425 people in 2018, and the people in 2019 were 186,834 people [8].

The increasing population, the need for land, settlement, and urban development infrastructure, will change the structure of land cover, which has implications for removing land cover vegetation. It is feared that this could increase global warming.

Urban emissions account for 44% when viewed from direct emissions [9]. The primary sources of CO\textsubscript{2} in urban areas are traffic, room heating, industrial processes, and respiration. Urban respiration comes partly from anthropogenic sources such as decomposition of garbage and human respiration and partly from soil and vegetation [10].

One of the efforts in controlling GHG emissions is to maintain plants' function as GHG emission absorbers, especially carbon dioxide emissions. In urban areas, plants' presence is susceptible to changes in land function, thus threatening the existence of plants that serve to produce oxygen and absorb carbon dioxide. The process of each plant is the same as absorbing carbon dioxide, but the ability to absorb CO\textsubscript{2} of each plant varies depending on the type of plant, plant age, number of plants, and the surrounding environmental conditions.

The purpose of this research is to analyze the factors causing the increase carbon dioxide emissions in urban areas, especially Prabumulih City and its plant-based control using causal loops or causal diagrams developed with dynamic system approaches.

2. Materials and methods

This study uses identification using a causal loop by determining the causal relationship of each CO\textsubscript{2} eq emitting source variable and its control efforts. Jay W. Forrester first introduced dynamic systems at the Massachusetts Institute of Technology (MIT) in the 1950s to solve complex problems that arise due to the causal dependence of various variables in the system. Causal Loop Diagram (CLD) is a mapping that shows the causal relationship between variables and arrows from cause to effect. CLD describes how system variables are related to each other through text, arrows, and symbols. A variable is a cause-and-effect relationship (arrows from "cause" to "effect"), and each causal relationship shows positive (reinforce, denoted R) or negative (balancing, denoted by B) polarity to show how the causal variable changes when the variable causes it changed [11].

The sign (+) indicates if the causal variable increases, the effect variable will increase, and if the causal variable decreases, the effect variable will decrease. The sign (-) indicates if the causal variable increases, the effect variable will reduce, and if the causal variable decreases, the effect variable will increase.

3. Results and discussions
This study describes a causal relationship (causal loop) between one variable and another, which can be in the form of a positive causal relationship or a negative causal relationship. The concept used in this study is to examine sources that can increase CO$_2$eq emissions and efforts to control CO$_2$eq. The causal loop of the concept of emission sources, CO$_2$eq, comes from people's respiration emissions, transportation emissions, industrial emissions, land-use emissions, livestock emissions and waste emissions. Some variables can increase and decrease the source of emissions in Prabumulih City.

Previous research was conducted in Bogor City by applying the concept of loss-gain emission from urban population activities consisting of development, industry, households, livestock, use of electricity and gas, and transportation which are assumed to be activities that increase CO$_2$ (gaining emission). On the other side, the existence of green open space is accompanied by several efforts to control CO$_2$ emissions such as waste management, use of biodiesel, reforestation, and use of biogas are activities that reduce CO$_2$ emissions (losing emission) [12].

Based on Figure 1, the reinforcing loop (R1) shows that the population will increase when the birth rate grows. When the population increases, the birth rate will also increase. Loop Balancing (B1) shows that as the population increases, the death rate will increase; conversely, it will reduce the population when the death rate rises.

The birth rate (fertility) positively affects the population growth rate or increases the population. In contrast, the mortality rate (death) has a negative impact or a reducing factor on the population growth rate [13]. In 2015, Prabumulih City had 177,078 people and increased to 186,834 in 2019 [8]. It is feared that an increase in population accompanied by an increase in the need for land for activities will result in land conversion so that it can remove vegetation that functions as oxygen (O$_2$) producer and increases carbon dioxide (CO$_2$) emissions [14]. The relationship between population and CO$_2$eq emissions is that if the population increases, the population's activity will also increase. Residents produce CO$_2$ emissions from the respiration process, and population activities such as land, fuel, and transportation will also increase.

Loop balancing (B2) shows that the increase in total CO$_2$eq emissions increases the need for CO$_2$eq absorbent plants and will increase the area of vegetated land. The existence of increased vegetated land can reduce land-use emissions due to land-use change. Improving land-use emissions will increase the amount of CO$_2$eq emissions. Loop reinforcing (R2) shows an increase in total CO$_2$eq emissions increases the need for vegetated land, reducing total CO$_2$eq emissions. While Loop
balancing (B3) explains that increasing total CO₂eq emissions increases the demand for vegetated land and reduces land-use emissions where changes in vegetated land function can increase CO₂eq emissions. Plant types' choice to absorb CO₂eq must be by the surrounding environmental conditions so that the area of green open space (RTH) increases according to its ecological function in absorbing CO₂eq emissions. One type of plant with very high CO₂ absorption is Samanea saman or trembesi, which can absorb 28,488.39 kg/tree/year [15].

The concept of the dynamic model of CO₂ emission absorption in Bogor City uses combined mitigation in controlling CO₂ emissions, namely maintaining the minimum area of green open space, managing organic waste and livestock manure into biogas, substituting LPG with biogas, substituting motorized vehicle fuel, and greening [12]. But sometimes, its application is not optimal because of its effectiveness and minimal public interest. This study focuses on optimizing the fulfillment of green open spaces by selecting types of plants that are by environmental conditions.

RTH is part of global warming mitigation, which is seen as one of the most implemented measures against rising greenhouse gas emissions than any other way [16]. The ecological approach by providing green open space is one of the best solutions because it is done by maximizing vegetation’s role in reducing pollutants. Plants available in nature can convert CO₂ gas into O₂ through the photosynthesis process. Plants, through their leaves, can also capture lead particles emitted by motor vehicles [17].

4. Conclusion

This study describes the causal loop of factors that increase the source of CO₂eq emissions. Some activities can increase CO₂eq emissions, such as increased population, vehicles, electricity consumption, garbage, livestock, and land use. To control the increase in CO₂eq emissions due to the increase in these factors requires plants that absorb CO₂eq emissions by the surrounding environment to absorb the resulting CO₂eq emissions. The results of the identification of the causal loop relationship between CO₂eq emission sources and their control can support the government in RAN-GRK, which is committed to reducing GHG emissions by 29% in 2030 business-as-usual (BAU) voluntarily and 41% with international assistance.

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