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DYNAMIC SYSTEM ANALYSIS OF GREEN OPEN SPACE IN MEDAN-INDONESIA

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ABSTRACT: The population of Medan has been increasing from 2015 until 2019 which causes rapid and uncontrolled population and residence densification in urban area. The increase in the need for space to accommodate the increasing population growth has caused vulnerability of the change from the use of GOS (Green Open Space) to land use such as residences, industry, and services. The change in the land use will save negative impact on environmental condition if it is not handled immediately. Therefore, it is necessary to control the land use, viewed from the availability of GOS which is begun by analyzing the pattern of distribution, types, and characteristics of each GOS. The objective of the research was to analyze 1) the change in using land in each sub-district in five years (2015-2019) and 2) Some factors which influenced the dynamic change in using GOS to become used land in Medan. The research used 3 (three) stages of design: 1) literature study, 2) gathering the data (primary and secondary data), and 3) discussion on the result of processing the data. The result of the research showed that 1) Since the period of 2015-2019 Medan has experienced a very dynamic change in land use. The most significant change was as follows: residential land increased to 829 hectares, industrial land increased to 87 hectares, and service land increased to 476 hectares while vegetation land (GOS) such as wet rice field decreased to 18 hectares, mixed plantation land decreased to 116 hectares, swamp forest land decreased to 956 hectares, but dry field increased to 656 hectares, and 2) The simulation results suggest that a decline occurs in the area of green open spaces throughout the simulation year period, i.e. from 7.405 Ha (2015) to 2.023 Ha (2028); the total population during the simulation year period which formerly was equal to 2.210.624 inhabitants (2015) will have increased to 2.454.920 inhabitants (2028); while the temperature from 28.14^{o} C (2015) increases to 28.50^{o}C (2028); and finally, GDRP during the simulation year period which formerly was equal to IDR 164.721,82 billion (2015) increases to IDR 315,465,92 billion (2028).

Keywords: *Dynamic System, Green Open Space, Landuse, Medan*

1. INTRODUCTION

Urban land area is divided into built land and unbuilt land. Built land consists of residence, industry, commerce, service, and offices [1] [2][3]. Meanwhile, unbuilt land is vegetation open space or it is usually called, green open space (GOS) which consists of wet rice field, mixed plantation, swam land, and so on. GOS is vegetating open space in an urban area which functions as recreation area, socio-culture, aesthetics, urban physic, ecology which have high economic value for human beings and urban development [19]. GOS can be an urban forest, an urban garden, graveyards, a playing field, a green belt, a highway, a railway track, and a river bed [7] [11] [16]. However, its existence as a space with its ecological function has made GOS as one of the land functions which is usually ignored in constructing and developing a town [14]. GOS plays an important role in providing the freedom of movement for its users since urban activity and development increases rapidly according to the needs of the people who live in it [18].

The land use area in Medan will be increasing along with urban development. The result of the analysis on *Ikonos* image map in the period of 2015-2019 showed that the most changing use of land was GOS (built land) such as industrial land increased to 122.24 hectares, service land increased to 257.45 hectares, and residential land increased to 763.38 hectares. Meanwhile, for vegetation land or GOS such as swamp forest land decreased to 160,03 hectares, mixed plantation decreased to 7.45 hectares, wet rice field decreased to 130.68 hectares, open land decreased to 852.04 hectares, while dry field increased to 6.91 hectares [1] [4] [5] [6] [7].

The decrease in the GOS area is caused by the development of Medan on a large scale, identified by the increase in the number of populations and its activities which indirectly causes high pressure on the use of space. The existence of GOS in urban area is often removed by other needs such as the enlargement of residential area, shopping center, and other commercial activities so that its quality and quantity will be decreasing each time [8] [9] [10] [11] [12]. On the other hand, along with the increase in the number of populations, green space in urban area becomes highly needed. The quality and the quantity of GOS should always be adjusted to the increase in population so that comfortable, productive, and sustainable Medan can be created.

Urban land consists of built land and unbuilt land. Land use includes residences, industry, commerce, services, and offices. Meanwhile, unbuilt land is vegetation open space which is usually known as GOS which includes wet rice field, mixed plantation, swamp dry field, and so on. GOS constitutes vegetation open space in urban area which is functioned as recreation area, socio-culture, aesthetics, urban physic, and ecology which have high economic value for human beings and urban development [13] [14] [15] [16] [17] [18]. GOS can be in the form of an urban forest, an urban garden, graveyards, a playing field, a green belt, a highway, a railway track, and a river bed However, its existence as a space with its ecological function has made GOS as one of the land functions which is usually ignored in constructing and developing a town [14]. GOS plays an important role in providing the freedom of movement for its users since urban activity and development increases rapidly according to the needs of the people who live in it [18].

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The decrease in the GOS area is caused by the development of Medan on a large scale, identified by the increase in the number of populations and its activities which indirectly causes high pressure on the use of space [4] [19] [20] [21] [22].. The existence of GOS in urban area is often removed by other needs such as the enlargement of residential area, hopping center, and other commercial activities so that its quality and quantity will be decreasing each time. On the other hand, along with the increase in the number of populations, green space in urban area becomes highly needed.

2. RESEARCH METHODS

2.1. ReseachLocation

The research was conducted in Medan, Provinsi Sumatera Utara. This town represents the high rate of population growth as what has occurred in the other metropolitan cities. The population growth has triggered the rapid rate of change in using land in urban area which is used for residence and settlement, commerce, services, and industry. The research took 6 months, from March until September, 2019. It consisted of three stages – gathering and classifying the data, analysis and synthesis, and concept and planning. In general, this research consisted of 6 stages as follows: preparation, gathering the data, analysis, interpreting the result, checking the field, and organizing the research. Preparation stage included the activity of selecting the research topic, library research, making the proposal, gathering the data which was done through the activity of gathering secondary data from the Agencies such as Bappeda and Landscaping Agency and primary data by checking the field. Various techniques of gathering the data would be explained below.

2.2.Technique of Analyzing the Data

Techniques of analyzing the data in this research were as follows: Identifying the changes from using GOS to the land use was performed with work stages – by classifying GOS and the used land using spatial analysis which included the processes of geometric correction using ArcGis software on the maps which had already been prepared. The classifying process was continued after the process of correction and digitations had been done in order to get the maps of the changes in land use and the distribution of GOS.

The model is a form made to replicate a symptom/structure/system, or description (abstraction) of a system. The model consists of 3 types: (1) quantitative models: mathematical, statistical, and computer; (2) qualitative models: Delphi, causal diagrams, cross-impact matrices, and matrix morphology; and (3) model of the iconic [19]. Among the three types of models, one of the quantitative models are often used in environmental analysis is system dynamics. system dynamics method is widely used in environmental studies because some considerations like:

a. Following the change of time (dynamics)
b. Complexity problems both detail complexity and dynamic complexity
c. Non-linear (nonlinearity),
d. There is a feedback [20]

[21][22][23][24][25][26] explains that modeling with System Dynamics is a perspective and set of conceptual tools that enable to understand the structure and dynamics of complex systems.

System Dynamics is also a rigorous modeling method that enables us to build a simulation of complex systems and use them to design more effective policies and organizations.

[22] [23], states that the basic methodology of system dynamics is a system analysis. A system is defined as a set of elements which interact with one another [24] [25] [26] [27] [28] [29] [30]. A system can consist of several sub-systems, where the system definition is also applicable on it. Interactions that occur within it all the time will affect the state of the system components. The system structure is determined by the relationship between its elements. Meanwhile system boundary will separate the system from its environment (figure 1).

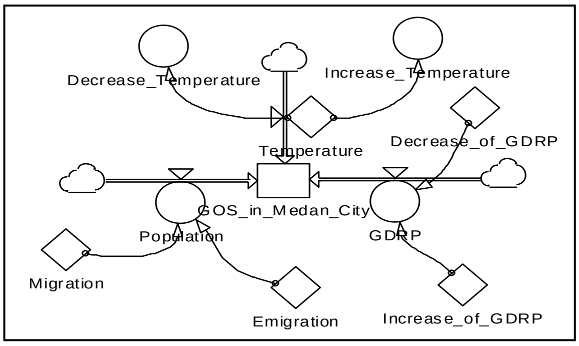

Figure. 1. Causal Loop Diagram (CLD) of Green Open Space

System dynamics involves the study of the relationships between feedback structure and dynamic behavior, there is a great impetus to try to infer dynamic behavior from representations of structure. That impetus has apparently led to a set of definitions of the polarities of causal-loops that are phrased in terms of behavior over time. As with definitions of causal links, so is with causal loops: the existence of rate-to-level links invalidates the traditional definitions of positive and negative loops in causal-loop diagrams. In this section the difficulties with the traditional definitions are noted, with the discussion focusing particularly on rate-to-level links, hidden loops, and net rates. The section ends with a brief analysis of a causal-loop which, together with the rest of the paper, cast grave doubt on the possibility of defining the polarity of causal loops in terms of dynamic behavior [31]

Positive and negative feedback loops are the building blocks of system dynamics. While a complete specification of the feedback structure of a system requires specifying levels (states) and rates, the essential components and interactions in a system can be communicated quickly and concisely in a causal-loop diagram [32].

2.3. Materials and Data of the Research

Materials used in this research were a set of computers and this equipment for the processing and analyzing the data. The materials used were as follows: Laboratory equipment: computer hardware with GIS (ArcGIS) software and image processor software (Er Mapper),Software Are View with extension, SPSS Statistics 17.0 software, Global Positioning System (GPS), a compass, and the other supporting materials which were used to find out control point coordinate position of the land used to determine the training area (sample area) of vegetation land. Base map of Indonesia from the Geospatial Information Agency. The research used primary and secondary data. Primary data were gathered by conducting in-depth interviews with stakeholders concerning priority of the policy. Secondary data included the data of population, used urban/land utilities and vegetation land, and other processing result data.

3. RESULTS AND DISCUSSION

3.1.The Change in Land use in Medan in the Period of 2015 - 2019

The result of the research, using *Ikonos* satelite image [15] showed that Medan, from 2015 until 2019 underwent a very dynamic change in land use (Figure 2 and Figure 3).

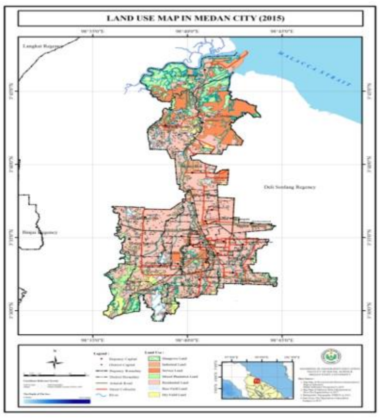

Figure 1. Landuse Map in Medan (2015)

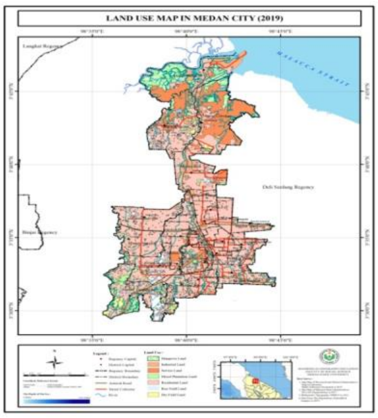

Figure 3. Landuse Map in Medan (2019)

The most significant change in land use, seen from figure 6, was residential land which increased to 892 hectares, industrial land increased to 87 hectares, and service land increased to 476 hectares while vegetation land (GOS) such as wet rice field decreased to 18 hectares, mixed garden land decreased to 116 hectares, mangrove land decreased to 956 hectares but dry field land increased to 565 hectares. All in all, the dynamic change in land use in Medan in the period of 2015-2019 was presented in Figure 4.

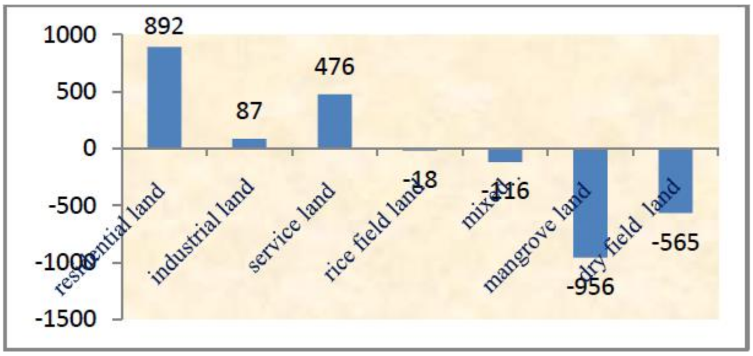

Figure 4. The Dynamics of Land Use Change in Medan (2015 -2019)

The rate of change in GOS in Medan from 2015 until 2019 decreased 6.24% each year. Sub-districts which underwent the the highest rate of decrease in GOS each year was Medan Labuhan Sub-district which decreased 19.81%, followed by Medan Sunggal Sub-district 15.16%, Medan Belawan Sub-district 13.53%, Medan Tuntungan Sub-district 11.71%, Medan Marelan Sub-district 10.69%, Medan Deli Sub-district 6.04%, Medan Johor Sub-district 6.28%, Medan Selayang Sub-district 4.05%, Medan Helveetia Sub-district 3.38%, Medan Denai Sub-district 3.02%, Medan Polonia Sub-district 1.69%, Medam Amplas Sub-district 1.51%,Medan Tembung Sub-district 0.79%, Medan Barat Sub-district 0.60%, Medan Kota Sub-district 0.48%, Medan Timur Sub-district 0.48%, Medan Timur Sub-district 0.48%, Medan Perjuangan 0.06%, Medan Petisah Sub-district 0.06, Medan Maimun Sub-district 0.36%, Medan Baru Sub-district0.12%, and Medan Area Sub-district 0.18%.

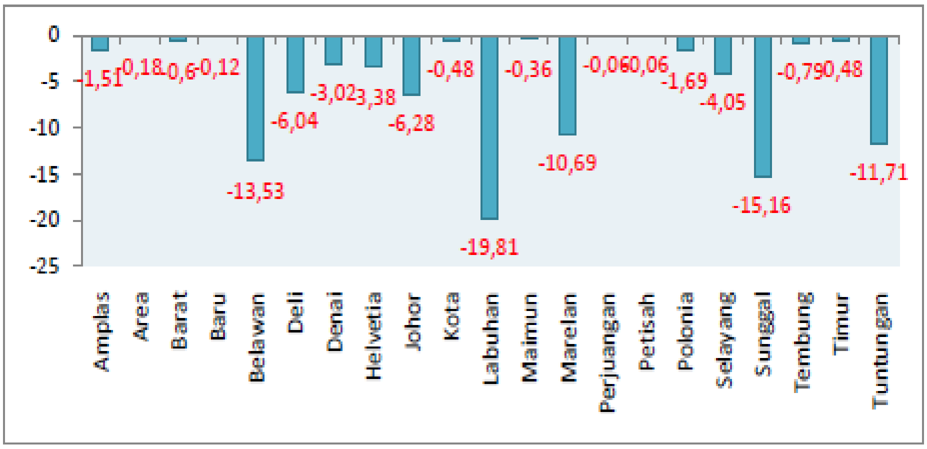

Figure 5. The Dynamics of Land Use Change Sub-Districts in Medan (2015 -2019)

The need for land use in Medan is increasing, along with the increase in the population growth and the people's economic activities. The implication of the variety of cultivation function of urban area emphasizes on GOS as urban ecological protection area . This is because the accessibility to urban infrastructure is able to attract various activities which can change the use of vegetation land to used land. Consequently, urban development tends to undergo the shift of its functions to urban fringe or Sub-district BWK (Urban Area Part). This phenomenon is known as the process of urban sprawl as part of the consequence of the rapid dynamic change in using urban land. The change of

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function of GOS to be used land cannot be avoided easily due to this tendency. Some cases show that when there is a change in using land in a certain area, in a short term the lad in its vicinity will be changed in its function progressively.

The spread and the change in GOS to be used land are caused by two factors. First, the development of residence and industry area will cause the accessibility to that area to be more favorable to develop residences and industry which will eventually bring about the increase in demand for land by investors or land speculators so that the price of the land in its vicinity will automatically go up [19] [20] [21] [30] [31] [36] [37]. Secondly, the increase in land price can encourage the people in the vicinity to sell their land. The buyers are usually the people from outside the location and not the local people. In consequence, there will be changeable land which is generally vulnerable to the process of land change of function.

Dynamic change from using GOS to be used land tends to be irreversible which is difficult to be returned to the original one. If it can be returned to the original function, it will take a lot of energy, cost, and time, and it will possibly cause social and cultural conflicts.

3.2. Establishing and Simulating Dynamic Models

The basic concept for the model developed in this research is a dynamic model which is comprised of three sub main systems, namely (1) Biophysical, (2) Social and (3) Economic. Simulation was undertaken for these three sub systems in accordance with a predetermined scenario.

The biophysical components are comprised of swamp forests, mixed forests, paddy fields, dry land, and open land significantly determine increases in the area of green open spaces in Medan. Results of the simulation for the sub-model of green open space areas in Medan City, the beginning of the simulation year (2015) was equal to 7.405 Ha, a decline at the end of the simulation year (2028) into 2.023 Ha. Likewise, the same trend also applies for the temperature in Medan City, the beginning of the simulation year (2015) reached 28,14°C, at the end of the simulation year (2028) the temperature will have increased to 28,50°C. Results of the simulation in terms of the social sub-model (population) indicate an increasing trend of the population number in Medan, which at the beginning of the simulation year (2015) was equal to 2.210.624 inhabitants while at the end of the simulation year (2028) the population number increases into 2.454.920 inhabitants.

Based on the results of the simulation of the GDRP sub-model, indicate an increasing trend in the amount in which at the beginning of the simulation year (2015) amounted to IDR 164.721,82 billion in 2028 until the end of the simulation year, it increasing to IDR 315.465,92 billion.

Table 1. The Existing Simulation Results for the Dynamic System Model of Green Open Space

Year	Green Open Space	Temperature	Population	GDRP
2015	7.405	28,14°C	2.210.624	164.721,82
2016	6.991	28,16°C	2.229.416	176.317,52
2017	6.577	28,19°C	2.248.208	187.913,22
2018	6.163	28,22°C	2.267.000	199.508,92
2019	5.749	28,25°C	2.285.792	211.104,62
2020	5.335	28,28°C	2.304.584	222.700,32
2021	4.921	28,30°C	2.323.376	234.296,02
2022	4.507	28,33°C	2.342.168	245.891,72
2023	4.093	28,36°C	2.360.960	257.487,42
2024	3.679	28,39°C	2.379.752	269.083,12
2025	3.265	28,42°C	2.398.544	280.678,82
2026	2.851	28,45°C	2.417.336	292.274,52
2027	2.437	28,47°C	2.436.128	303.870,22
2028	2.023	28,50°C	2.454.920	315.465,92

Source: Data Processing by Powersim in 2015 – 2028

Directions in terms of the allocation of green open space areas directed towards establishment of a green city in Medan City have already required improvement with fundamental management related to the biophysical sub-model, the social sub-model and the economic sub-model. Based on the test results and the verification in terms of the simulation and historical proximity, then strategic policy can be used in the next step as one of the standards for the model of green open space management towards the establishment of a green city in Medan City.

4. CONCLUSION

The result of the research, using *Ikonos* satelite image, showed that Medan in the period of 2015-2019 will have undergone dynamic change in land use. The most significant change of using land use in which residential land increases to 892 hectares, industrial land increases to 87 hectares, service land increases to 476 hectares, but vegetation land (GOS) such as wet rice field decreases to 18 hectares, mixed plantation land decreases to 116 hectares, and swamp forest land decreases to 956 hectares although dry field increases to 656 hectares. In the dynamic analysis model, there is a relationship among the biophysical, social, and economic components. The simulation results suggest that a decline occurs in the area of green open spaces throughout the simulation year period, i.e. from 7.405 Ha (2015) to 2.023 Ha (2028); the total population during the simulation year period which formerly was equal to 2.210.624 inhabitants (2015) will have increased to 2.454.920 inhabitants (2028); while the temperature from 28.14ºC (2015) increases to 28.50ºC (2028); and finally, GDRP during the simulation year period which formerly was equal to IDR 164.721,82 billion (2015) increases to IDR 315,465,92 billion (2028).

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