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Low Carbon Emission Development Model with System Dynamic approach in Luwu regency

Muhammad Dahri Syahbani Rusman[1]; Rijal Idrus[2]; Andang Suryana Soma[3]
[1]Graduate School of Hasanuddin University, Makassar, South Sulawesi, Indonesia.
[2] Faculty of Marine Science and Fisheries Hasanuddin University, Makassar, South Sulawesi, Indonesia.
[3]Faculty of Forestry Hasanuddin University, Makassar, South Sulawesi, Indonesia.
muhammaddahrisyahbani@gmail.com (correspondence author).

ABSTRACT

Development of low carbon emissions System Dynamics Modeling that can be done is development in the mangrove sector. One of the forest ecosystems that is quite good at carbon sequestration is the mangrove ecosystem which can store four times more carbon than tropical forests The *system dynamics* approach is carried out by understanding the dynamic behavior of a phenomenon and identifying changes in mangrove cover and emissions. The method used to see land use changes from year to year is the spatial analysis method, then the data is analyzed using a dynamic system. This research will be conducted in Luwu Regency, South Sulawesi Province. This research was carried out for 2 months, namely October 2021 to November 2021. The results of the analysis revealed that the area of mangrove cover decreased in 2011 reaching 3,014 Ha until in 2020 it reached 1,677 Ha, there are several types of land use that have changed in area, one of which is a decrease in primary dry forest land cover and secondary dry forest and an increase in area in settlements and agricultural land. The results of the model simulation show that in the existing condition the mangrove area in the luwu regency in 2011 was 3,014 ha and in 2020 it was 2,507 ha, based on the BAU, the condition of the mangrove area in 2030 is estimated to be 2,895 ha, in 2045 it will be 2,511 ha and in 2060 it will be 2,199 ha. Analysis of Low Carbon Emission Development in Mangrove Ecosystems in Luwu Regency shows that the proportion of mangrove emission release and absorption reaches equilibrium by 2047 in a fair scenario.

Keywords: System Dynamic; mangrove; model simulation; scenario.

1. INTRODUCTION

National Development Planning makes low-carbon development one of the priorities in efforts to reduce greenhouse gas emissions in order to encourage and strengthen environmental and forestry management and integrate programs related to the environmental quality index. Low carbon emission development is a development activity that is planned and implemented with the aim of improving welfare while reducing the impact of carbon emissions caused by development activities [1-3].

The low carbon emission development carried out in this study is development in the mangrove sector. One of the forest ecosystems that is quite good in carbon sequestration is the mangrove ecosystem which can store four times more carbon than tropical forests [4-6]. Luwu Regency is one of the regencies in South Sulawesi that has mangrove potential with a high percentage of area based on data from the KP3K Statistical Report of the Marine and Fisheries Service. The area of mangroves in 2020 in Luwu Regency is ±12,869 Ha [7-9].

System Dynamics Modeling is to increase understanding of the relationships that occur between the feedback structure and the dynamic behavior of a system, so that various policies can be developed in order to improve the behavior of problems that occur. In building the modeling, some data related to low-carbon development planning is needed in order to calculate carbon emissions from development activities [10-12].

In the transition area there is a mangrove ecosystem which is a transition or combination of terrestrial and marine ecosystems where there are habitats for various types of birds, primates, reptiles and various other types of habitats. Community activities in the region are pond cultivation. The change of mangroves into pond areas is a relationship between the two resulting in a negative relationship. So to find out the extent of changes in mangrove area and emission reductions that occur in the mangrove area, this study uses a scientific approach through System Dynamics modeling. This approach is carried out to identify the variables of change in the object of study.

This research takes the theme of the model of the Dynamics of low-carbon development systems in mangrove ecosystems. The *system dynamics* approach is done by understanding the dynamic behavior of a phenomenon and identifying the variables of the change. In addition, the System Dynamics approach also tests the sensitivity of the model through intervention to these variables, for use in the policymaking process.

2. METHOD

a. Research Time and Location

This research will be conducted in Luwu Regency, South Sulawesi Province. This research was carried out for 2 months, namely October 2021 to November 2021 by going through the stages of data collection and data analysis.

b. Research Procedure

The System Dynamics methodology aims to get about the workings of a system based on causal (*causal*) philosophy. System modeling and simulation is created with *Powersim* 10 software. There are several stages that must be followed in the application of System Dynamics, namely:

(1) Identification and Analysis of Existing Conditions

Identifying existing conditions that support low-carbon planning and development in Luwu Regency and activities supported to achieve low-emission development. As for what will be obtained in the Identification and Analysis of Existing Conditions as follows: (1) Identification of Stakeholders and Intrepretation of programs/activities related to regional low-carbon development. (2) Sources and potential emission reductions, identify areas and activities that have the potential to be emission sources/removals, based on coverage, regional conditions, sectoral emission activities and production, and regency characteristics.

(2) Running Model Dynamics System

a. Identify Issues, Objectives, and Limitations

Issue identification is carried out to find out the point of view of the real problem, so that when making modeling it can lead to the core of solving the problem raised. Problem formulation and selection of limitations of existing conditions.

b. Model Conceptualization

Model conceptualization is the process of describing the concept of the entire model to be compiled. The stage carried out in the conceptualization phase of the model is to identify the overall components involved in the modeling and group them based on the interactions between these components.

The conceptual stage of the simulation model is by making structural specifications, decision rules, parameter estimation and consistency tests with predetermined goals and limitations. This constrained system is a system that encompasses all concepts and variables that are interconnected with a defined dynamic problem.

c. Model Simulation and Evaluation

Simulations are carried out by incorporating policy factors/policy interventions (according to the desired scenario) into the built model. Policy changes will affect other variables so that overall it will affect system performance. This condition is a description of the real conditions that may occur. The result of these changes will be observed on the desired table or graph of variables.

d. Model Verification and Validation

Model verification is proof that a computer model that has been compiled at an earlier stage is capable of simulating the abstract model studied [13,14]. In another sense, verification is a process to ensure that the computer program created and its application is correct. The way it is done is to test the extent to which the computer program created has shown behavior and response that corresponds to the purpose of the model [15].

e. Model Implementation

Models are used to facilitate decision-making or alternative problem solving. In the phase of using the model, alternative data collection is carried out which may be taken and then run through modeling. Once declared valid, the model can be used as a tool to understand the system. Furthermore the *input* values of the model are changed to produce a specific output of the model. The *input* values are changed according to the desired scenario. Based on the results of the model *output*, the best scenario is selected that will be used as the basis for decision making. The research steps can be seen as follows

3. RESULTS AND DISCUSSION

a. General Conditions of Research

- Location and Area

Geographically, the location of Luwu Regency is located at 2°3'45" to 3°37'30" South Latitude and 119°15" to 121°43'11" East Longitude from the North Pole with the benchmark position of South Sulawesi Province, thus the position of the capital of Luwu Regency is in the northern part of South Sulawesi Province with a distance of about 300 km from Makassar City which is the capital of South Sulawesi Province.

Luwu Regency has a Geostrategic area bordering five Regencies and one Bay, with a coastal length of 72 miles, a mountainous area of 63.99 percent and a plain and coastal area of 36.01 percent, with geographical conditions consisting of mountains, plains and coasts representing a very strategic economic potential and potential in development.

The administrative area of Luwu Regency is approximately 3,000.25 km^2 consisting of 22 sub-districts which are completely divided into 227 villages/kelurahan. Latimojong Subdistrict is the largest subdistrict in Luwu Regency, the area of Latimojong District is recorded at around 467.75 km 2 or about 15.59 percent of the area of Luwu Regency, followed by then North Walenrang and West Walenrang district with an area of about 259.77 km 2 or about 8.66 percent and 247.13 km ^{2} respectively or about 8.24 percent. While the district that has the smallest area is North Belopa District with an area of approximately 34.73 km^2 or only about 1.16 percent. The area of each district and the number of district can be seen in Table 1.

Table 1. Area of district and number of districts of Luwu Regency

No	Subdistrict Area	Area (km^2)
1	Larompong	225.25
2	South Larompong	131.00
3	Suli	81.75
4	West Suli	153.50
5	Belopa	59.26
6	Kamanre	52.44
7	Belopa North	34.73
8	Bajo	68.52
9	Bajo West	66.30
10	Bassesangtempe	178.12
11	Latimojong	467.75
12	Bassesangtempe North	122.88
13	Bupon	182.67
14	Ponrang	107.09
15	South Ponrang	99.98
16	Bua	204.01
17	Walenrang	94.60
18	East Walenrang	63.65
19	Lamasi	42.20
20	North Walenrang	259.77
21	West Walenrang	247.13
22	Lamasi East	57.65
Luwu County		3000.25

- **Land Closure**

Jenis the land cover of Luwu Regency and its area for 2011 and 2020 namely airport/port, secondary mangrove forest, primary forest, secondary forest, plantation forest, open land, settlement, plantation, dryland agriculture, dry land mixed with shrubs, savannas, rice fields, shrubs, swamp thickets, ponds and water bodies. For land cover in 2011 and 2020 can be seen in table 2.

Table 2 Land Cover Area of Luwu Regency in 2011 and 2020

No	Land cover	2011	2020
1	Airport/Port	77	81
2	Secondary Mangrove Forest	3,014	2,507
3	Primary Forest	20,710	3,578
4	Secondary Forest	52,742	66,712
5	Forest Plantations	192	158
6	Open ground	99	1,226
7	Settlement	742	4,383
8	Plantation	269	278
9	Dryland Agriculture	250	25,515
10	Dryland Agriculture Mix Shrubs	111,312	82,573
11	Savanna	2,147	2,210
12	Paddy	23,415	31,418
13	Shrubs	63,096	57,657
14	Marsh Shrubs	-	7
15	Pond	11,330	11,052
16	Body of Water	1,493	1,536
Total		**290,888.49**	**290,888.49**

b. Identification and Analysis of Existing Conditions

1. Stakeholders and related with Building low carbon area Service Forestry Province South Sulawesi, Dinas Marine and Fishing and Service Milieu Live Province South Sulawesi, program/Activities related with Building low carbon area be Rehabilitation Mangrove/Planting mangroves on area shore beach
2. Low-carbon development activities are carried out through the AKSARA website platform. There are no activities of the luwu regency government that have the potential to be an absorption/source of emissions in the mangrove sector.

c. Running Model

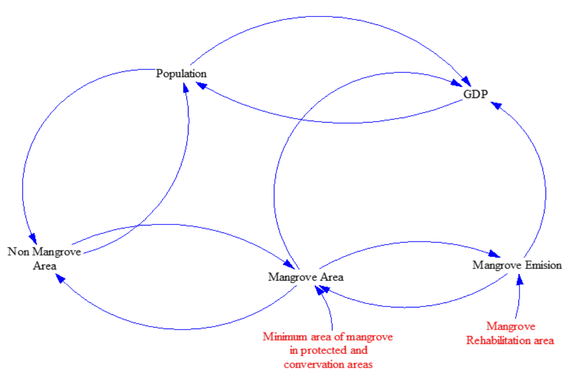
1) Identify issues, objectives and limitations

The need for a regional low-carbon development plan document as a regional reference to achieve regional development plans [4]. The main objective of this system is to Identify Supporting Existing Conditions related to Low Carbon Emission Development in Mangrove Ecosystems in Luwu Regency and Evaluate Low Carbon Emission Development in Mangrove Ecosystems in Luwu Regency. In building the modeling, several analyses related to low-carbon development planning are needed in order to calculate carbon emissions from the mangrove sector. The analysis is land cover change analysis, Net Emission Analysis and Emission Absorption and Release Analysis.

2) Conceptual Model

To be able to conceptually understand the low-carbon emission development model, continue with computer modeling and simulation through *a system dynamics* approach. Practically dealing with the process of implementing a mental model (conceptual / qualitative) system *thinking* product in such a way (using mathematical equations and input the values of its variables) until it finally becomes a simulation model that is ready to run. The process of approaching *system dynamics* can be seen in the *causal loop diagram* as follows:

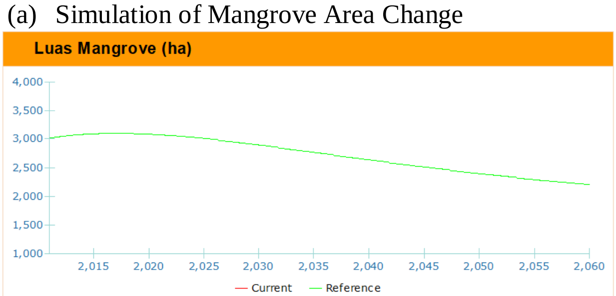
3) Model Simulation



Figures 1 Causal Loop Mangrove Sector

Simulations of systemic modeling results are used to see patterns of behavioral tendencies of the model. The results of model simulations that give rise to sensitive variables are analyzed as a basis for formulating the policies needed in improving system performance. In the analysis of the linkage system between these sub-models, simulations were carried out to predict mangrove area and future reductions in mangrove emissions for a period of 50 years (2011-2060). Thus, these models and simulations apply within the limits of such assumptions. The simulation results of the system model for a period of 50 years are as follows:

(a) Simulation of Mangrove Area Change



Figures 2 Mangrove Area in a Baseline Scenario

Based on the graph, it can be seen based on the chart above that in a period of 50 years (2011-2060) the condition of mangrove forests in the baseline scenario in Luwu Regency has decreased very significantly, covering an area of 3,014 ha from 2011 to 2,199 ha in 2060. The decrease in the area of mangrove forests has resulted in a decrease in the ability to absorb emissions.

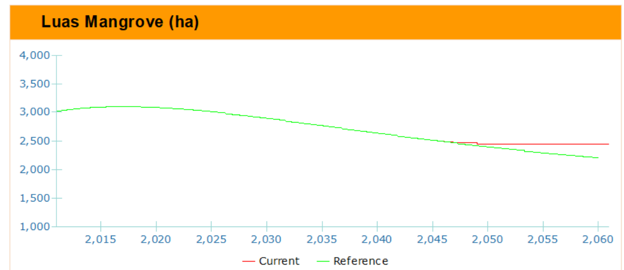
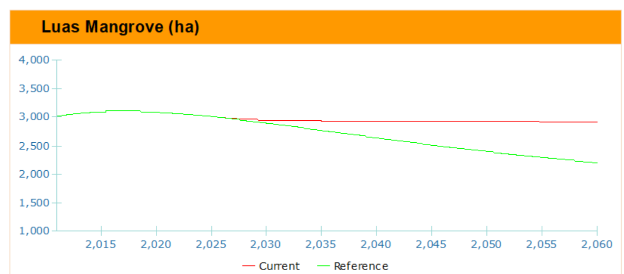


Figure 3 Mangrove Area in a Fair Scenario

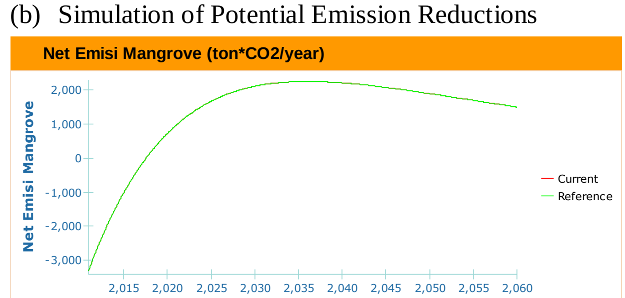
Based on the picture above, it can be seen that within 50 years (2011-2060) in the fair scenario the condition of mangrove forests in Luwu Regency has increased from the baseline scenario in 2060, which is an area of 2,199 ha to 2,446. The increase in the area of mangrove forests in this fair scenario has resulted in an increase in the ability to absorb emissions.



Figures 4 Mangrove Area in an Ambitious Scenario

Based on the picture above, it can be seen that within 50 years (2011-2060) the condition of mangrove forests in Luwu Regency has increased in the ambitious scenario in 2060 covering an area of 2,921 Ha from the condition of the fair scenario with an area of 2,446 Ha. The increase in mangrove forest area in this ambitious scenario results in an increasing ability to absorb emissions.

(b) Simulation of Potential Emission Reductions



Figures 5 Net Mangrove Emissions in a Baseline Scenario

Based on the results of the analysis, it is known that the net emission of mangrove forests in the baseline scenario has reached net emissions in 2011 to 2017 because it has reached 0 tons / year emissions and increased in 2018 by 286 tons / year to 1,479 tons / year in 2060. The low absorption of mangrove emissions derived from changes in other land cover to become eroded and the high release of emissions from mangrove changes to other land cover is one of the causes of the decrease in net mangrove emissions under baseline conditions. The biggest emission release from mangroves is in the form of changes in mangroves to pond areas then followed by changes in mangroves to other land areas. With the addition of carbon emission absorption due to changes in other land cover into mangroves. The reduction of mangrove emissions in Luwu regency under baseline conditions can be overcome to increase emission absorption in Luwu Regency.

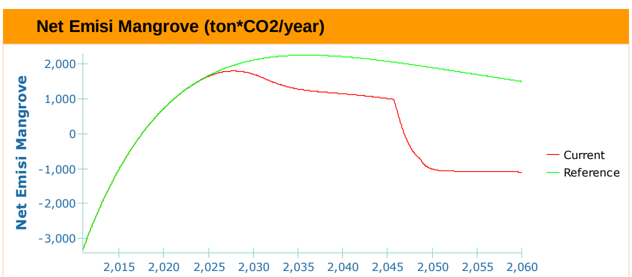


Figure 6 Net Mangrove Emissions in an Fair Scenario

Based on the results of the analysis, it is known that the net emissions of mangrove forests in the baseline scenario have reached net emissions in 2011 to 2017 because they have reached 0 tons / year emissions and increased in 2018 by 286 tons / year and in 2046 have reached net emissions. The presence of Forest rehabilitation policy at baseline conditions in Luwu Regency of 400 Ha. Reduction of mangrove emissions in Luwu regency in baseline conditions can be resolved to improve emission absorption in Luwu County.

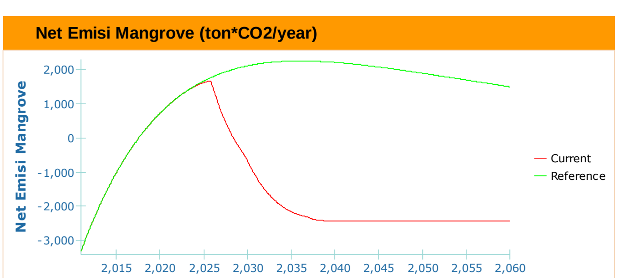


Figure 7 Net Mangrove Emissions in an Ambitious Scenario

Based on the Ambitious scenario with a forest rehabilitation policy on baseline conditions in Luwu Regency of 600 ha can help net mangrove forest emissions decrease in 2028 from the previous condition in 2018 of 286 tons/year. The low absorption of mangrove emissions derived from changes in other land cover to become eroded and the high release of emissions from mangrove changes to other land cover is one of the causes of the decrease in net mangrove emissions under baseline conditions. The reduction of mangrove emissions in Luwu regency under baseline conditions can be overcome to increase emission absorption in Luwu Regency.

4) Model Validation

Model performance validation is a test of the extent to which the performance of the constructed model *(model output)* corresponds to the performance of a real system, thus qualifying as a fact-abiding or academically accepted scientific model. Output validation can be done by comparing the output data of the built model with empirical data [5]. Some types of statistical test techniques that can be used in model performance validation testing include absolute *mean* error (AME) and *absolute variation error* (AVE), with the tolerable deviation limit being 5-10% [6]. This performance validation test was performed on the mangrove area sub-model. After going through various improvements both structurally and functionally, the simulation results of the submodel show similarities between the simulation results and the baseline data. Through the application of calculation formulations for the mangrove area variable, a match value of 9% was obtained. Thus, the data from the simulation of the mangrove area sub-model are ultimately quite accurate, so the model developed can be declared structurally valid and academically acceptable.

5) Implementation Model

The implementation of the low-carbon emission development model can be applied in Luwu Regency to the mangrove sector by integrating ecological, economic, social, and institutional aspects. For the implementation of this model, the factors that must be considered are: (1) the environmental impact of each industrial and service activity, (2) human resources, (3) the availability of supporting infrastructure, especially transportation networks, (4) commodities that have *comparative advantange*, *competitive advantage*, *value added* and *multiplier effects* high, and (5) environmental conservation through the use of land resources efficiently, optimally, fairly and maintained ecosystem balance.

4. CONCLUSION

a. In the existing condition, the mangrove area in luwu regency in 2011 covers an area of 3,014 ha and in 2020 an area of 2,507 ha, based on BAU, the condition of the mangrove area in 2030 is estimated to be 2,895 ha, in 2045 covering an area of 2,511 ha and in 2060 covering an area of 2,199 ha.

b. Analysis of Low Carbon Emission Development in Mangrove Ecosystems in Luwu Regency shows that the proportion of mangrove emission release and absorption reaches equilibrium by 2047 in a fair scenario.

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