A simulation model for urban development in Bandar Lampung City, Lampung, Indonesia

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Abstract. The unprecedented growth in population put pressure on urban land suitability. Besides that, the deterioration of infrastructure facilities, traffic jam, and disaster like flood and landslide could be happen more severe in a few years later. This study attempted to find out the projection of population growth and suitability of urban land in order to be carried out sustainably. Land use suitability assessment is a key determinant in any urban planning and decision-making process. The variables taken for the study are slope, altitude, and land cover. This study provided the information not only the existing urban land cover pattern but also the simulation of population growth and land suitability for the establishment in future.

Keywords : GIS, spatial dynamics, system dynamics, urban land suitability

1 Introduction
Needs of built up area always increase, it use as agricultural land, plantation, and also settlement. While forestry land are increasingly limitid due to increase of the built up area. It is impact to the capacity of land. Community awareness of land capacity for the very lack and the role of government that is also take part in the operation could cause irregularity in regional development. Regional development, should be in harmony with land carrying capacity so that it can be optimize the land cover without impair the green spaces such forest, green openspaces, and cultural heritage which is needs to keep balance of nature. According to law UU No. 26/2007 on Spatial Planning Restrictions of green spaces and built up area maximum 30:70 become the method that must be obeyed in order that two sides balance. This regulations also became the basic for the government to plan the regional spatial planning.

The preparation of the regional spatial planning must be accommodate a long-term growth of population from year to year. In this study researchers aim to probe the spatial dynamics of availability land and the suitability land in the future, so it can be sustainably land.

2 Method
This research used the spatial dynamics approach with quantitive analysis. The dynamics of population growth will cause the increase of built up area, over the function of land will decrease the availability land. System dynamics model can predict the population growth and the availability land over the years. Regarding the spatial obtained from driving factors to decide the suitability land.

In this study, there are two variables which are Social such as natality rate, mortality rate, and migration rate, and physical/geographical condition such as land cover, infrastructure, and landscape.
Table 1. Population Growth in Bandar Lampung City 2009-2017 (Disdukcapil Bandar Lampung, 2018)

| No | Year | Population Growth | Crude Birth Rate | Crude Death Rate | Migration (In) | Migration (Out) |
|----|------|-------------------|------------------|-----------------|---------------|----------------|
| 1  | 2009 | 0.9%              | 0.6%             | 0.2%            | 0.8%          | 0.3%           |
| 2  | 2010 | 2.1%              | 0.4%             | 0.2%            | 2.5%          | 0.7%           |
| 3  | 2011 | 1.9%              | 1.1%             | 0.3%            | 1.8%          | 0.8%           |
| 4  | 2012 | 3.7%              | 2.2%             | 0.3%            | 2.6%          | 0.9%           |
| 5  | 2013 | 4.3%              | 2.3%             | 0.1%            | 3.2%          | 1.1%           |
| 6  | 2014 | 2.0%              | 2.2%             | 0.2%            | 1.9%          | 2.0%           |
| 7  | 2015 | 1.9%              | 2.1%             | 0.2%            | 2.3%          | 2.4%           |
| 8  | 2016 | 1.9%              | 2.0%             | 0.2%            | 2.1%          | 2.0%           |
| 9  | 2017 | 7.9%              | 4.7%             | 0.2%            | 4.3%          | 1.4%           |
| 10 | 2018 | 3.0%              | 1.9%             | 0.2%            | 2.4%          | 1.3%           |

The process of the prediction the population growth and the built up area with system dynamics is by using Powersim. It is important to test the accuracy, it tested using Absolute Mean Error (AME). The result of the simulation is expected to get AME value <30%. If its valid then the model can proceed to the next step. The process of creating the driving factors are by using GIS tools which is Euclidean Distance for interpreting continuous data effectively and efficiently.

3 Result

a. System Dynamics Model

The system dynamic is a method to study of meahanism of complex, dynamic, non-linier, through a feedback structure between elements in the system [1]. As a system thinking is a basic concept for understanding of system dynamics. The system is the whole interaction between elements of an object within a certain environmental boundary that works to achieve certain goals [2]. Urban area is a system in which transactions occur between built and human land [3]. The process of intertwined interactions will lead to patterns and goals, which will always cause feedback loops from one variable with other variables. In the dynamic system model, known as Causal Loop Diagram or disclosure of the occurrence of causal relationships into a particular image.

Problems and conditions in the field are simplified in the form of models that illustrate the causal relationships of population growth and the availability land and are described in causal loop diagram. Based on the problems described in the CLD model the number of inhabitants and built up area are dynamic main variables. As follows figure 1.
Based on the Causal Loop Diagram there are five feedback, 3 positive feedback and 2 negative feedback.

- Loop R1: Increase in total population → increase in total population growth → increase in total population.
- Loop B2: Increase in total population → increase in mortality rate (caused to population decrease) → decrease in total population.
- Loop R3: Increase in total population → Increase in total land demand → decrease in land carrying capacity → Increase in population pressures → increase in pressures factors of migration out → increase in migration out → population decrease → increase in total population.
- Loop B4: Increase widespread in built up area → increase in built up area pressure factor → increase → fast increase in built up area growth rate → increase into total built up area.
- Loop R5: Increase widespread in built up area → fast increase in built up area growth rate → Increase widespread in built up.

Then Stock and Flow Diagram made according to the Causal Loop Diagram, that is showed by Figure 2.
b. Simulation Result
The simulation results of the built up area and population growth can be seen in Figure 3. It can be seen that the population grows rapidly along with the number of built-up areas that increase in magnitude and experience a slowdown and form a horizontal line, and decreasing the number of availability land.

![Figure 3. System Dynamics Graph](image)

The built up area in Bandar Lampung City has over 64% in 2018 and in 2020 has reached 69.5% or 13,711.17 ha of the total area of Bandar Lampung which has an area of 19,722 ha. According to Law No. 26/2007 concerning Spatial Planning, ideal land is built up to 70% and 30% to green spaces. But in 2030 Bandar Lampung city has reached the limit with 87.4% built up area.

| No | Year | Population | Built up Area | Percentase |
|----|------|------------|---------------|------------|
| 1  | 2017 | 1,079,485  | 12,235,12     | 62.04%     |
| 2  | 2020 | 1,187,746  | 13,711,17     | 69.52%     |
| 3  | 2025 | 1,392,841  | 15,760,65     | 79.91%     |
| 4  | 2030 | 1,633,351  | 17,238,94     | 87.4%      |

Table 2. The Simulation of Population and Built up Area in Bandar Lampung City result

c. Model Validation
The result of validation test for amount of population in 2009-2017 on this model, showing the AME value is 1.9% and the model is valid. The AME value of built up area is 22% and the model is valid.

![Figure 4. Graph of differences in actual numbers and simulation numbers of population growth and built up area](image)

d. Suitability Land
Driving factors are used to obtain land suitability, so that the development of built areas is not in areas that are dangerous for the population and for the environment. Driving Factors consist of distance from roads, distance from rivers, distance from coastline, distance from points of interest (POI), slope, and elevation. Each driving factor has a weight based on class which affects the decision of humans to build buildings.
Table 3. Driving Factors

| No | Parameter                        | Class       | Score |
|----|----------------------------------|-------------|-------|
| 1  | Distance from Roads              | <100 m      | 3     |
|    | (Journal Planning for Urban Region and Environment, Vol 3 No 1, 2014) | 100-750 m   | 2     |
|    |                                  | >750 m      | 1     |
| 2  | Distance from Rivers             | <50 m       | 1     |
|    | (PP RI No.38/2011 to Rivers)     | 50-100 m    | 2     |
|    |                                  | >100 m      | 3     |
| 3  | Distance from Coastline          | <100 m      | 1     |
|    | (PERMEN PU No. 40/PRT/M/2007)    | 100-2000m   | 2     |
|    |                                  | >2000 m     | 3     |
| 4  | Distance from POI                | <100 m      | 4     |
|    | [5]                              | 100-400 m   | 3     |
|    |                                  | 400-1000m   | 2     |
|    |                                  | >1000 m     | 1     |
| 5  | Slope                            | 0-3%        | 3     |
|    | [6]                              | 3-15%       | 2     |
|    |                                  | 15-40%      | 1     |
|    |                                  | >40%        | 1     |
| 6  | Elevation                        | <2 m        | 1     |
|    | [6]                              | 2-7 m       | 1     |
|    |                                  | 7-25 m      | 3     |
|    |                                  | 25-100 m    | 2     |
|    |                                  | 100-500 m   | 1     |
|    |                                  | >500 m      | 1     |

Figure 5. (a) Distance from Roads, (b) Distance from Rivers, (c) Distance from Coastline, (d) Distance from POI, (e) Slope, (f) Elevation

Based on FAO (1976) land suitability for semi-detailed level mapping (scale 1: 25,000-1: 50,000) is divided into Highly Suitable (S1), Moderately Suitable (S2), and Marginal Suitable (S3). Highly Suitable is the land that does not have a limiting factor that is significant and does not affect the
productivity of the land significantly. Moderately Suitable is land that has a limiting factor that can affect productivity, so it requires additional input, but can still be overcome by the population. Marginal Suitable is land that has a severe limiting factor that affects productivity, and the need for assistance or interference from the government or the private sector. Not suitable is land that has a very heavy limiting factor.

The maximum score of six variables is nineteen, then the suitability class is divided into three classes, namely 13-19 (Highly Suitable), 7-12 (Moderately Suitable), 0-6 (Marginal Suitable). Scoring results show land suitability (figure 6).

![Suitability land Map of Bandar Lampung City in 2018](image)

**Figure 6.** Suitability land Map of Bandar Lampung City in 2018

4 Discussion

In this study, the needs of built up area assumed that in one family consists of five person (father, mother, and 3 child) minimum occupancy is 100m$^2$ (SNI 03-1733-2004). Development of built up area based on the suitability land, each grid represents 1 ha (100x100m) then in 1 ha represents 500 populations. Shown the dynamics of built up area in in 2017, 2020, 2025, and 2030 in figure 7. 2020 is the year when built up area reached 69.5%, while 2030 is the end of Regional Spatial Planning for Bandar Lampung City and according to the result of simulation the built up area has reached 87%. 2040 is year when the the percentage of built up area was reached 95% and in 2050 the development slowly up to 98% but this was approaching the limit of the suitability land, forests, and cultural heritage. In 2050 is almost no suitability land because the built up area has been spread all over the highly suitable. Only left the moderately suitable land that allowed be built, but this has risk for the environment and population.
Figure 7. Simulation of built up area in 2017, 2020, 2025, and 2030.

5 Conclusion
Increase in population growth effect to increase in needs of built up area and it caused to decreasing of availability land. In 2030 built up area reach 87% it means that the suitability land has reached the limit in this year. This simulation can be a standard and to predict what is the next step for maintain the sustainable land, and does not risk to the environment and the population.

6 References
[1] Soesilo, Budhi, dan Karuniasa, Mahawan 2014 Permodelan System Dynamics. (Jakarta: Lembaga Penerbit Fakultas Ekonomi Universitas Indonesia)
[2] Muhammad Ali, Setia Hadi, Bambang Sulistyantara 2016 Study on Land Cover Change of Ciliwung Downstream Watershed with Spatial Dynamic Approach. (Procedia) 227 p 52-59.
[3] Forrester, J. W. 1969 Urban Dynamics (Massachusetts: The M.I.T Press)
[4] Supriatna 2014 Penerapan System Dynamics Berbasis Sistem Informasi Geografis untuk Model Ketersediaan Lahan Kawasan Estuari Cimandiri, Jawa Barat (Indonesia: Seminar Nasional Eco-City) p 28-37.
[5] Otzurk, Derya 2017 Modelling spatial changes in coastal areas of Samsun (Turkey) using a cellular automata-markov chain method (Turkey:Tehnicki vjesnik) 24 (1) p 99-107.
[6] Sandy, I Made 1977 Penggunaan Tanah (Land Use) di Indonesia. Publikasi No. 75 (Jakarta: Direktorat Tata Guna Tanah, Direktorat Jenderal Agraria Departemen Dalam Negeri)
[7] Rusli, Said 2014 Pengantar Ilmu Kependudukan (Jakarta: LP3ES)
[8] Xiaoming Xu, Ziqiang Du, Hong Zhang 2016 Integrating the System Dynamic and Cellualar Automata Models to Predict Land Use and Land Cover Change (Elsevier) 52 p 568-579.
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