Distribution Pattern of Settlement in 2032 based on Population Density in Bengkulu City

Natasya Syafira Putrie¹, Dewi Susiloningtyas²*, Supriatna³, Mentari Pratami⁴
Department Geography, Faculty of Matematikas and Natural Science, Universitas Indonesia
E-mail: dewi.susiloningtyas@sci.ui.ac.id

Abstract. Population and development activities that are increasingly urgent will demand higher settlements. Low population density and become higher along with population growth and centralization at the center which will shape the pattern of settlement spread. The research method used in this study is the Modeling of Cellular Automata and Geographic Information Systems. The purpose of this study is to identify patterns of population distribution in 2032 in the city of Bengkulu. This study shows the CA models in changing temporal land support capacity and forward prediction in 2032 models with physical and social data in Bengkulu City. The study is to help local authorities to better understand and address complex land use systems and develop better land use. The results showed that the distribution pattern in the western part of Bengkulu City had a high level of density and distribution pattern from the settlement of North-East-South clustering had a lower population density and random settlement distribution patterns.

1. Introduction
Bengkulu City is a destination for population migration in the province of Bengkulu. Concentration of residents in the city of Bengkulu encourages population compaction and results in increasing demand for residential land or built land. The large number of settlement developments carried out, it will urge the physical development of the city of Bengkulu. Population is very influential in development because the population as actors as well as being the development targets carried out.

The main consequence of rapid population increase in the world is rapid land use change, alarming global environmental changes and transformation of fertile land into urban land. Based on the current growth trend, the position and role of Bengkulu City can become one of the growth centers in Bengkulu Province, (http://ciptakarya.pu.go.id). Population activities can determine the dynamics of city and regional life. In the population analysis consists of an analysis of population growth rate, projected population and projected population density.

The growth and development of the city of Bengkulu is not only influenced by the function and position of the city in the regional sphere but the internal state of the city itself which considers the potential aspects of the city but the existing capabilities and limitations. Reviewing problems in the city area can be a key consideration that determines the feasibility of a development plan that will be prepared for the future.
Cellular Automata Model (CA) is a discrete agent based method used in cell-based applications that is most widely used to simulate land use change in the last few stages. In contrast to the research conducted by Lagarias (2012) this study looked at changes in multitemporal land cover in 2002-2010-2017-2032 so that the carrying capacity of residential land can be analyzed in 2032 in the City of Bengkulu. Based on Bengkulu City Regulation No. 14 of 2012 concerning; Bengkulu City Spatial Planning for 2012-2032.

This research focuses on residential land in the city of Bengkulu. Research on the analysis of the carrying capacity and capacity of the area related to settlement needs in the City of Bengkulu is carried out with the aim of knowing the carrying capacity and carrying capacity of the land in meeting the needs of settlements in 2032. This research will be discussed in broad outline covering the population analysis that will review the analysis of projected population density based on 2016 with the next 2032 years supported by the concept of Cellular Automata.

2. Materials and Methods

2.1. Study Area
The research location was located in the city of Bengkulu, which was administered by 8 subdistricts. Muara Bangkahulu District, Serut River, Singgaran Pati, Selebar, Kampung Melayu, Gading Cempaka, Ratu Agung and Teluk Segara.

2.2. Material
1. Satellite Data: Landsat path / row 125/63 Landsat 5 TM imagery for 2002, Landsat 7 ETM for 2010 and Landsat 8 OLI for 2017. Satellite acquisition date for March to June.
2. Software: Idrisi selva 17, ENVI 5.1, and GIS Arc 10.1.

2.3. Data Analysis
1. Image classification: land cover classification is carried out using a guided classification in ENVI 5.1 software. The classification process produces a map of residential land cover for 2002, 2010 and 2017.
2. Changes in land cover: changes in residential land cover are carried out by detection of post-classification changes.

The data needed is secondary data obtained from the relevant agencies. The method used in this analysis can be reviewed by looking at the classification of 2016 population density in the city of Bengkulu with the calculations that have been done and the data obtained based on data from BPS Bengkulu City in 2016.

In this study the method used is spatial analysis by overlaying data spatial to produce a new mapping unit that will be used as an analysis unit. The overlay method is used to get the level or class of land. Furthermore, this analysis uses the concept of sustainable development in the form of development efforts that aim to meet current needs. This form of effort to implement the concept of sustainable development is by carrying out development in accordance with the carrying capacity of the region which can be defined as the maximum population that can be supported by an environment without damaging the environment. The focus on analyzing the capacity of this area shows how much land area in Kota Bengkulu Subdistrict which is used as a study case can accommodate housing in accordance with the development of the population. Furthermore, the formula used to calculate the regional carrying capacity analysis and in determining the capacity in each sub-district is described in equation 1 with modifications:
Information:
\[ n = \frac{P\% (B\% \times L) \times k}{100} \]  
(1)

Information:
- \( n \): the capacity of the island / population that can be accommodated (soul)
- \( P\% \): number of percentage of housing area in sub-district (50%)
- \( B\% \): percentage of cultivated area (50% of district area)
- \( L \): total district area (km²)
- \( k \): number of people in one family (3 people / family)
- \( 100 \): minimum area of land for one family (m²).

CA-Markov models: Markov chains and CAs are both discrete dynamic models in time and circumstances. One problem with Markov is that it does not provide a geographical explanation. Transition probabilities may be accurate by category, but there is no knowledge of the spatial distribution of events in each land use category. CA is used to add spatial characters to the model. Idrisi Selva 17 integrates CA with Markov very well. In this study, we used Idrisi GIS software to simulate settlement land cover in Bengkulu City. The driving factor used in this study is the slope, height of the area, distance from the road, distance from the river and distance from the coast.

Carrying capacity of residential land: to analyze the carrying capacity of residential land. Required size of land that is suitable and suitable for settlements, and required standards or criteria for the needs of the land of each population. Formula to calculate the carrying capacity of regions for settlements (equation 2).

\[ \text{DDPM} = \frac{LP_m}{JP} \]  
(2)

Carrying capacity index value:
- \( \text{DDPM}>1 \), means that the carrying capacity of the settlement is high, it is still capable of residents to settle in their territory.
- \( \text{DDPM}=1 \), means that the optimal support capacity of completion, there is a balance
- \( \text{DDPM}<1 \), means that the carrying capacity of the settlement is low, unable to accommodate residents to settle in the area.

3. Result and Discussion

3.1. Population density in the city of Bengkulu

The city of Bengkulu, administratively covers 8 sub-districts. Muara Bangkahulu Subdistrict, Serut River, Singgaran Pati, Selebar, Kampung Melayu, Cempaka Girls, Ratu Agung, Ratu Samban, and Segara Bay. Population growth and economic development in the city of Bengkulu are quite fast becoming one of the factors of land conversion. Based on the analysis of population density according to BPS data in 2016, the calculation of the population density level in the city of Bengkulu has been carried out. For more details, see table 1 below:
Table 1. Classification of Population Density of Bengkulu City.

| No. | Sub District      | Area (Km²) | Percentage (%) | Population Density in 2016 | Classification |
|-----|-------------------|------------|----------------|-----------------------------|----------------|
| 1   | Selebar           | 46.36      | 30.56          | 1457.58                     | Low            |
| 2   | Kampung Melayu    | 23.14      | 15.25          | 1704.17                     | Medium         |
| 3   | Gadis Cempaka     | 14.42      | 9.51           | 3021.83                     | Medium         |
| 4   | Ratu Agung        | 11.02      | 7.26           | 4599.2                      | Medium         |
| 5   | Ratu Samban       | 2.84       | 1.87           | 8921.83                     | High           |
| 6   | Singaran Pati     | 14.44      | 9.52           | 2895.68                     | Medium         |
| 7   | Teluk Segara      | 2.76       | 1.82           | 8506.57                     | High           |
| 8   | Sungai Serut      | 13.53      | 8.92           | 1756.6                      | Medium         |
| 9   | Muara Bangkahulu  | 23.18      | 15.28          | 1890.66                     | Medium         |
| 10  | Kota Bengkulu     | 156.69     | 99.99          | 34754.12                    | High           |

Source: BPS of Bengkulu City in figures, 2016.

Table 2. Population Density Classification (Soul/ha).

| Population Density Classification (Soul/ha) |                  |
|-------------------------------------------|------------------|
| Low                                       | < 1457.58        |
| Medium                                    | 1457.59 - 8322.6 |
| High                                      | > 8322.7 - 9893.55 |

Based on table 1 and 2, the City of Bengkulu is a city with a relatively moderate population density, seen from the sub-districts in the city of Bengkulu the dominant population density is classified as moderate, including the sub-districts of Kampung Melayu, Cempaka Girls, Ratu Agung, Singaran Pati, Sungai Serut, and Muara Bangkahulu. In terms of the lowest population density, the subdistricts in Bengkulu City are Selebar sub-districts with a population density of 1457.58 (soul/ha). For sub-districts that can be categorized as sub-districts with the highest density, Kecamatan Ratu Samban is 8921.83 (soul/ha).

3.2. Research Result

3.2.1. The Population Density of Bengkulu City in 2016
The carrying capacity of an area is closely related to the conditions and capabilities of the ecosystem. The carrying capacity of the region for settlements can be interpreted as the ability of the region to provide settlement land to accommodate a certain population to live properly.

Population density is calculated based on the population of an area per area, so that population density can be identified in units of soul/ha (figure 1). Based on table 1, it can be seen for Ratu Samban, Teluk Segara, and Muara Bangkahulu Subdistricts that the population has exceeded the capacity of each sub-district. The total population of Ratu Samban Subdistrict in 2016 has exceeded the capacity of the island as much as 25,338 inhabitants, while the population in Teluk Segara Subdistrict has exceeded the capacity of 23,478 inhabitants, and for the population in the District of Muara Bangkahulu which has exceeded the capacity of 43,826 soul. Based on the above conditions, from the 9 sub-districts which were used as the case
in this study, 3 of them were already in critical condition as seen from the availability of land for settlements in accordance with the existing population.

Figure 1. Map of Population Density Rate of Bengkulu City in 2016.

Table 3. Population Density Projections in 2016.

| No. | Sub District         | Area (Km²) | Percentage (%) | Population in 2016 | Population Density in 2016 | Classification |
|-----|----------------------|------------|----------------|--------------------|-----------------------------|----------------|
| 1   | Selebar              | 46.36      | 30.56          | 67.574             | 1457.58                     | Low            |
| 2   | Kampung Melayu       | 23.14      | 15.25          | 39.435             | 1704.17                     | Medium         |
| 3   | Gadis Cempaka        | 14.42      | 9.51           | 43.575             | 3021.83                     | Medium         |
| 4   | Ratu Agung           | 11.02      | 7.26           | 50.683             | 4599.2                      | Medium         |
| 5   | Ratu Samban          | 2.84       | 1.87           | 25.338             | 8921.83                     | High           |
| 6   | Singaran Pati        | 14.44      | 9.52           | 41.814             | 2895.68                     | Medium         |
| 7   | Teluk Segara         | 2.76       | 1.82           | 23.478             | 8506.57                     | High           |
3.2.2. Land Support Capacity of Settlements

a. Modeling Cellular Automata for Land Support Capacity
In Settlements Bengkulu City Land Cover in 2032 has an area of 18,690.47 ha. Cellular Automata modeling results show that the land area for settlements in 2032 is 5,993.15 ha while the land requirements are in accordance with Peraturan Menteri Negara Perumahan Rakyat No.11/PERMEN/M/2008 concerning (α) Space Per Capita Needs by Zone Area that in the City Center Zone Space/capita needs are 16 m²/Capita and the population calculated through population projections in 2032 is 439,833/soul (table 3).

b. Carrying Capacity for Land for Settlements Based on the Bengkulu RTRWK
LPm (the area of land that is suitable for settlements) is obtained from the area of the Bengkulu RTRWK reduced by the prediction area of 2032 Bengkulu City so that the proper land area for settlements is 5,387.50 ha. Population in 2032 from the calculation of population projection in 2016 to 2032, the population in 2032 of Bengkulu City is 439,833 inhabitants. While the area/capita (m²/capita) wide coefficient of need is based on the City Center Zone (Peraturan Menteri Negara Perumahan Rakyat No. 11/ PERMEN/2008) that is 16 m²/capita (table 4 dan 5).

| No | Sub District          | Area (Km²) | Percentage (%) | Population in 2016 | Population Density in 2016 | Classification |
|----|----------------------|------------|----------------|---------------------|-----------------------------|----------------|
| 8  | Sungai Serut         | 13.53      | 8.92           | 23.767              | 1756.6                      | Medium         |
| 9  | Muara Bangkahulu     | 23.18      | 15.28          | 43.826              | 1890.66                     | Medium         |
| 10 | Kota Bengkulu        | 156.69     | 99.99          | 359.49              | 34754.12                    | High           |

Table 4. The Capacity of Bengkulu City Subdistrict in 2016.

| No | Sub District          | Population in 2016 | Capacity     | Difference  |
|----|----------------------|--------------------|--------------|-------------|
| 1  | Selebar              | 67.574             | 2950.972737  | 2883.399    |
| 2  | Kampung Melayu       | 39.435             | 897.104247   | 857.6692    |
| 3  | Gadis Cempaka        | 43.575             | 72.2370725   | 328.6621    |
| 4  | Ratu Agung           | 50.683             | 222.5664659  | 171.8835    |
| 5  | Ratu Samban          | 25.338             | 15.63287088  | -9.70513    |
| 6  | Singaran Pati        | 41.814             | 373.140701   | 331.2901    |
| 7  | Teluk Segara         | 23.478             | 14.79382632  | -8.68471    |
| 8  | Sungai Serut         | 23.767             | 329.730592   | 305.9636    |
| 9  | Muara Bangkahulu     | 43.826             | 38.831064    | -4.99494    |

*) Difference is the capacity reduced by the current population.
Source: Calculation Results.

The advantage shows that in 2032 the DDPm value was 68.18 m²/capita, which means DDPm>1, the carrying capacity of the settlement was high and it was still able for residents to live. In other words, the city of Bengkulu can still accommodate an increase of 68.18 m²/capita.
Table 5. Calculation Results of Bengkulu City Space Needs.

| LPm                  | Large (ha) | Large (m²) | Space Needs | Meter/Soul |
|----------------------|------------|------------|-------------|------------|
| RTRWK Bengkulu - Prediction 2032 | 5.387, 50  | 53.874,9   | 790128      | 68,18      |
| Conformity - Prediction 2032   | 15.341,37  | 153.413,7  | 790128      | 109,22     |

Source: Data processing 2018.

c. Carrying Capacity of Residential Land based on Land Suitability

LPm (the area of land that is suitable for settlements) is obtained from the area of land Settlement Development Sustainability in suitability for settlements of 15,341.37 ha minus the area of prediction in 2032. The population in 2032 of the estimate from 2016 to 2032 The population in 2032 Bengkulu City 439,833 inhabitants. While the area/capita (m²/capita) wide coefficient of need is based on the City Center Zone (Peraturan Menteri Negara Perumahan Rakyat No. 11/PERMEN/2008) that is 16 m²/capita.

Figure 2. Map of Comparison of Land Cover Predictions for Year 2032 and RTRW.

The results show that in 2032 the DDPM value was 109.22 m²/capita which means DDPM>1, the carrying capacity of settlements was high and was still able to accommodate the population to settle. In other words, the city of Bengkulu can still accommodate the increase in settlements by 109.22 m²/capita (figure 2).

In calculations of land carrying capacity, based on the Bengkulu RTRWK and Conformity. The carrying capacity of the land based on the Bengkulu RTRWK shows a result of 68.18 m²/capita while the carrying capacity of land for settlements based on suitability shows a yield of 109.22 m²/capita. Calculation of residential land carrying capacity based on the Bengkulu RTRWK and Conformity results in a value of DDPM>1 which means that the carrying capacity of settlements is high and is still able to accommodate residents to settle in 2032.
4. Conclusion and Recommendation

4.1. Conclusion
Limitations in the development of residential areas move horizontally so that they need a large enough area. During the last 15 years period (2002-2017) changes in settlement land cover experienced a wide increase of 1,919.40 ha, especially in the northern and eastern parts of Bengkulu City. Sub-districts that experienced a rapid increase in settlement/built land cover were Muara Bangkahulu Subdistrict of 465.59 ha and Selebar District of 912.43 ha.

Based on the carrying capacity of residential land based on the calculation of the Bengkulu RTRWK, the DDPm value was 68.18 m²/capita and the carrying capacity of land for settlements based on the calculation of the suitability area showed a result of 109.22 m²/capita. DDPm value based on RTRWK is smaller than based on Conformity because in the Conformity area this study only looked at 6 factors that influence the distance from the road, distance from the river, distance from the coast, slope, height of the area and protected forest area.

4.2. Recommendation
Nine of Bengkulu City Subdistrict is seen from the availability of land for the provision of settlements based on the number of inhabitants that must be accommodated in the next few years, assuming a permanent population growth, the population that inhabits the three sub-districts will exceed the existing capacity. Based on these characteristics, an immediate effort is needed in the framework of a good distribution pattern based on the population that has exceeded the capacity. These efforts include the use of appropriate land needs to be done so that the region can develop sustainably in meeting the needs of its population.

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