Understanding the Urban Population Density and Growth concentration in Palembang Indonesia

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Abstract

This research is to understand the current condition of Density, population, and growth concentration in the city of Palembang. As one of the oldest cities in Indonesia, Palembang has been one of the twelve fastest growing cities in Indonesia, with more than one point six million people in 2018. According to the 2018 United Nations booklet (Nations, 2018) the Indonesian cities will grow with the annual rate of 2.4% to 6%, and undoubtedly this growth will impact the city's urban fabric. This paper uses the Landsat images, and OpenStreetMap (OSM) data sets combined from the 2018 Population statistics in Palembang by overlaying the data to examine the statistical growth and urban density in the city of Palembang. The maps will also use the space syntax method and natural street analysis to determine the human behavior and traffic movement pattern and how the current urban layout should be examined. This street network's potential will serve as a narrative for further development to the city of Palembang.

Kata kunci: density, population growth, natural street, space syntax, Palembang.

Abstrak

Judul:* *Memahami Populasi dan Kepadatan Urban serta Konsentrasi Pertumbuhan di Palembang Indonesia

Riset ini bertujuan untuk memahami kondisi terkini yang berkaitan dengan kepadatan, pertumbuhan populasi dan konsentrasi pertumbuhan kota Palembang. Palembang sebagai salah satu kota tertua di Indonesa merupakan salah satu dari dua belas kota di Indonesia dengan opulasi 1.6 juta orang yang tumbuh dengan sangat cepat. Menurut booklet United Nations tahun 2018 (Nations, 2018) *Kota-kota Indonesia akan mengalami pertumbuhan tahunan rata-rata sebesar 2.4% hingga 6% dan tentunya pertumbuha tersebut akan memiliki dampak terhadap pertumbuhan urban kota-kota tersebut. Tulisan ini menggunakan Landsat images dan juga menggunakan OpenStreetMap (OSM) sebgai basis data set serta menggabunkan dengan data statistic populasi kota Palembang tahun 2018. Peta-peta yang dihasilkan juga akan di Analisa menggunakan metoda Space Syntax dan Natural Street untuk menentukan peilaku perkembangan kota serta pola pergerakan dan bagaimana pola Urban tersebut harus ditinjau lebih lanjut. Potensi dari jaringan jalan tersebut akan menjadi narasi untuk pengembangan kota Palembang Selanjutnya*

Keywords: *kepadatan, pertumbuhan populasi, natural street, space syntax, Palembang.*

Introduction

Urban population density is a piece of essential information to understand a particular city's growth concentration. The methods in analyzing these features have been proven challenging for researchers due to the limitation of the urban and geographical dataset that

is provided for public use. Through the use of internet media, the current Indonesian government has been providing information by using onemap feature, but unfortunately, those maps are still raw and often are not updated for present analysis purposes. Population density and the growth concentration in a city are essential to represent the economic activity in an urban environment (Wang, 2006).It is one of the necessary tools for urban designers to assess the development of urban areas. Large-scale analysis of a city has been challenging due to the limited data and time-consuming to evaluate these urban areas' density. In this paper, I am using Palembang as a case study to assess the urban population density and concentration of its growth using available tools to help further spatial research on the city of Palembang.

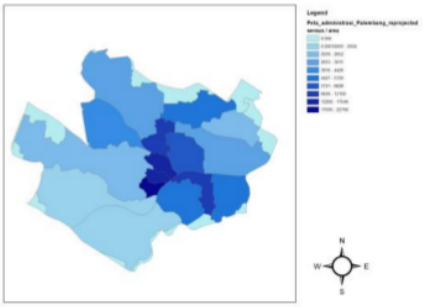

Figure 1. Density map of each administrative area in Palembang.
Map by Romdhoni, 2019

Palembang is the oldest city in Indonesia and has a population of 1,722,500 people in 2020, according to the world population review. Palembang's administrative size is 400.55 km2, where the overall population density is 3.617 people for every km2. The city of Palembang has gone through tremendous changes over the past three decades for only having a population of 878,732 in 1986. The growth has been doubling since then; indeed, this has a noticeable impact on the urban fabric of the city.
The research starts with the availability of census data from *Balai Pusat Statistik* provided for Palembang's 16 administrative zones. The datasheet needs to be visualized in detail since the dataset will not assess this case study's real urban density. The study is using Remote Sensing from Satellite images to determine the LULC / Land Use Land Cover as well as OpenStreetMap data that provides the current street centerlines to help determine the urban spatial density in the study area.

The map in **Figure 1** is showing the 16 administrative areas in the city of Palembang; Plaju, Ilir Timur Satu, Kalidoni, Sukarami, Seberang Ulu Dua, Kemuning, Ilir Timur dua, Alang Alang Lebar, Seberang Ulu Satu, Sematang Borang, Ilir Barat Dua, Ilir Barat Satu, Kertapati, Sako, Bukit Kecil, and Gandus. The collected data is added to the table of attributes in ArcMap to create a visual population density of each administrative area. The population density in this figure is the ratio between person per km2 by dividing the number of census data with the size of the area, and the map of Palembang shows that there are areas that have an overall high density of 22780 people/km2 and the lowest area show a density of 2000 person/km2.

Although this map shows an overall density in Palembang's administrative area, the map does not represent Palembang's actual urban density in terms of the number of the built-up area compared to the population ratio.

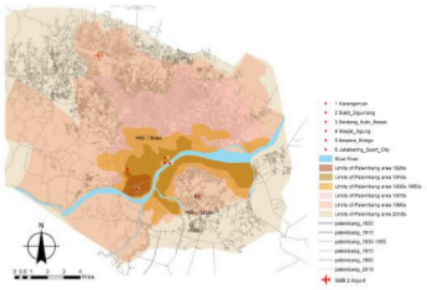

Figure 2. The map shows the main feature and historical morphological phases of Palembang.
Map by Romdhoni, 2018

Palembang's city boundaries have changed over time. The earliest source of city boundary was created around the 1820s, and today the city has since used the latest city boundary, with the total administrative size of 338.49 km2 shown in **Figure 2**. With the rapid city growth, the city has expanded merging with the neighboring administrative area, and the sum size of the city has doubled the size of its administrative area. This has raised a question if Palembang's administrative area has used the maximum growth of its administrative boundary? From this research, urban growth could be studied by analyzing the urban built area's growth concentration in Palembang.

Urban Density

Population and urban density have been linked together and creating a bond that affected each other. The urban form is an essential element in the planning process, while the urban density will create a critical formulation to the environment. The drawback of an urban density is the urban sprawl, where planners and urban designers focus on reducing the rigorous impact on an environmental and better understanding of the relationship between urban form, energy, and the environment. Studies in the environmental effects of the urban form and residential density have explained the qualitative value of the policy application in urban planning (Jabareen, 2006; Norman et al., 2006; York University (Jabareen, 2006; Norman et al., 2006; York University (Toronto & Lang, 1986). However, with current spatial analysis, it is possible to verify the urban density's quantitative value by using Remote sensing images to accurately define the urban density and urban population in a specific area.

The question that is also needed to be answered in this research is the maximum and optimal growth for and administrative boundary? This urban growth could be studied by analyzing the urban density and urban built area of Palembang.

Natural Street

The knowledge of topographical relationships is needed better to understand the relationship between the underlying street network. There have been many ways to enable urban analysts to see the scaling and living structure through quantitative analysis that could make human activities more predictable and work as a collective human movement behavior.

The more fundamental method that has been used in this field is the space syntax methods and measures in urban morphological studies. The space syntax has been a substantial body of research since the 1970s and developed by (B. H. Hillier & Hanson, 1984) that studies the networks of physical spaces on a structural environment and people's networks in society. This body of knowledge has evolved. The space

syntax method has been proven using the axial lines-based space syntax to define and predict human activities using the topology of space (B. Hillier, 2007). The natural street as a continuity in the space syntax theory is generated from an individual street segment with the same name and good continuity (Jiang et al., 2008). The natural street is more important in the city scale and rather different from the axial line analysis that view the segment analysis in a geometry-based rather than topology-oriented meaning that the natural street is better in predicting the human activities (Jiang et al., 2008; Jiang & Jia, 2011; Omer & Jiang, 2015). It is arguable the natural street analysis is showing a better scalling property of street network and demonstrating that

1. Natural street is a good representation in predicting the human activities

2. Neither street or line segment is able to capture the scaling pattern of human activities, but the parameters are converted to natural street or axial lines graph to have a good sense in human activities correlation.

It is essential to acknowledge that natural street is one of the best representations in terms of human activities and traffic prediction behavior and ways to conceptualize distances or spaces and the underlying scaling hierarchy of streets and street connectivity (Ma et al., 2019).

Methodology

The research is using a methodology based on the datasets analysis and using overlay mapping between different context. The first process is to figure out the population density in Palembang, by having the population from the BPS of Palembang shown in **Figure 3**. The second process is to determine the Land Use Land Cover / LULC of Palembang and to analyze the built up area in the city. This built up area is the converted as urban density that define the population concentration of Palembang.

After defining the urban population density, the third process in this research is defining the movement concentration and growth concentration in Palembang. This process is achieveable by overlaying the street centerline map and natural street with the linear density of street centerlines from the city of Palembang. In **Figure 3** we could see the census data collected from BPS that show the number of people and the size of the administrative zone in km2. The census spreadsheet data is than added to the attribute of the shape file in ArcMap to show the density of each administrative zone compared to the area size shown in **Figure 1**.

Peta_administrasi_Palembang

NAMOBJ	census	area
KERTAPATI	89597	43.541917
SEBERANGULU SATU	91619	16.584108
ILIRBARAT DUA	71267	3.128133
PLAJU	88265	15.430175
SEBERANGULU DUA	104209	8.551634
BUKITKECIL	48874	2.868432
GANDUS	64020	41.407929
ILIRTIMUR SATU	77102	4.994522
ILIRTIMUR DUA	93352	13.672767
KALIDONI	111030	28.362343
KEMUNING	91419	7.915482
ILIRBARAT SATU	137863	56.343537
SEMATANGBORANG	35821	13.507808
ALANG-ALANGLEBAR	96886	21.891926
SAKO	91753	17.355365
SUKARAMI	155590	42.922223

Figure 3. Census datasheet provided by the source: BPS in Palembang 2018

There have been previous research on the urban form and urban morphology of the city of Palembang and has provided valuable information on the

process of growth in the city of Palembang as well as the changes of urban form that has happened (Adiyanto et al., 2018; Nugroho, 2012). The result shows that the urban form of Palembang has transformed from linear city, to radial city and that the current state shows that Palembang is a multinucleated city (Anderson et al., 1996). This research fills the gap to show the core of density in the multinucleated form of Palembang and showing more embrio of nucleated points in the urban density in Palembang.

Methods

The method to define the LULC data is adopting the population census data of 2018 and the satellite images are using Landsat images that has been continually monitoring the earth since 1972; this continuation of data is beneficial on validating the long-term evaluation of the model. The satellite image data is obtained from U.S. Geological Survey (USGS) Earth Explorer resources https://earthexplorer.usgs.gov/ and the specific image chosen for site is using the lowest percentage of cloud cover (5%) and high-resolution tif images. In this research.

The remote sensing process is using the rational linear regression method to distinguish the impervious surface by implementing the Linear Spectral Mixture Analysis / LSMA (Wu & Murray, 2003) in combination with the ETM+ linear regression method to distinguish the VIS / Vegetable, impervious material and soil model (Bauer et al., 2007). This process will allow to predict the Built urban density pixel related to the impervious surface material.

The regression method is the value of tasseled cap transformations in the value of each band on the remote sensing data. This research and method has been developed and conducted by Joseph to verify the density value in Port-au-Prince, Haiti (Joseph et al., 2012). Built urban area is conducted by estimating the continuous imperviousness index using linear combination of image bands or ratios. While the dependent variable is the multivariate regression model to estimate continuous imperviousness index from the ETM+ image. The independent variables were derived from the six ETM+ bands with the array of blue, green, red, NIR, SWIR1 and SWIR2 with the three image ratios of NDVI, brightness, and greenness.

Table 1 ETM+ tesseled cap indices measurement

Index	Band 2 (Blue)	Band 3 (Green)	Band 4 (Red)	Band 5 (NIR)	Band 6 (SWIR 1)	Band 7 (SWIR 2)
Brightness	0.3029	0.2786	0.4733	0.5599	0.508	0.1872
Greenness	−0.2941	−0.243	−0.5424	0.7276	0.0713	−0.1608
Wetness	0.1511	0.1973	0.3283	0.3407	−0.7117	−0.4559

The tasseled cap indices in Table is giving a measurement value of Greenness, Brightness and wtness of each pixels in the 6 Landsat band (Band2, Band3, Band4, Band5, band6, and Band7). To calculate the Impervious surface using the Tasseled Cap index by implementing the statistical model of the multivariate regression (Yang, 2006)

$$IS = 1.285B - 0.189G - 231.757$$

Where ***IS*** is the imperviousness or Impervious urface index and **B** and **G** is the brightness and greenness derived from the tasseled cap transformation of the ETM+ image or using the Band 2 and Band 3. The adjusted R square value of this model is 0.91 and the standard error of the estimation is 8.5%. The imperviousness index map is represented in continuous with diverging sequential color scheme.

Result and Research Findings

The population density in this research is the dependent variable in the regression model. The population density is the measurement of the number of persons per km2. There have been several transformations of population density to maximize the model's fitness. The transformation of datasets is to show the built urban area density with the use of dependent population datasets for a particular value of the dependent variable to view the standard deviation to the density value. The density will then show the percentage of the value estimating the density of the study area and the model in **Figure 1** will be modified to visually show the difference in the density between the census data model with the built area density model shown in **Figure 8**. The estimation of this model is taking account of the independent variable of the location, also affect the relative condition of the study area and giving weight as neighbor part of the study area.

This research also shows the value of urban expansion with the dynamic change of the urban built of the spatial structure in the city. The value of change in the spatiotemporal data, with the dynamics of land use that represents the change in the quantity of land use in a unit time. The dynamics of land use with the extent of the urban expansion can be compared quantitatively according to the following formula:

$$LUDI = \frac{Ua - Ub}{Ua} \times \frac{1}{T} \times 100\%$$

Ua and Ub is the value of urban built areas at time a and b respectively, and T denotes the length of time from time a and time b and T is the unit value in year. LUDI is the Land Use Dynamic Index and show the annual rate of change in the area for the land use class.

Population Density and Analysis of Urban Expansion

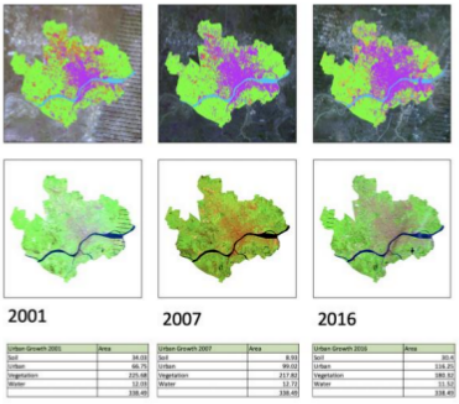

Figure 4. Urban density map transformation in the city of Palembang from 2001 to 2016
Map by Romdhoni, 2019

The initial identification for this research is comparing the Land use and Land Cover / LULC in Palembang into four categories of water, vegetation, urban, and soul defined by the administrative city boundaries. To identify each area, this result uses the tasseled indices value of each land-use

provided in previous research of (Joseph et al., 2012). Each index is calculated using the raster calculator and each band from the ETM+ Landsat 7 images, and creating new tif with various low and high value that shows the corrected images for Vegetation, Soil and Urban built area/house.

Based on the identification on the 2018 Landsat Image we could see the proportion of area in Palembang with the value of the urban area of 26.43% and the total value of vegetation, soil, and water of 73.57% from 338.49 km2 of the administrative area in Palembang.

Figure 5. The built urban areas in Palembang on 2018 shown in the green dot colors
Map by Romdhoni, 2019

The second identification of this research is verifying the growth distribution of the 16 administrative areas in Palembang. The 16 administrative areas in Palembang are respectively *Plaju* with 15.17 km2, *Seberang Ulu Satu* with 10.69km2, *Seberang Ulu dua* with 17.44km2, Kertapati with 42.56km2, Kalidoni with 27.92km2, Ilir Timur dua with 25.58km2, *Ilir Barat dua* with 6.22 km2, *Bukit Kecil* with 9.92km2, *Ilir Timur Satu* with 6.5km2, *Kemuning* with 9km2, *Sematang Borang* with 36.92km2, *Sako* with 18.04 km2, *Sukarami* with 51.46km2, *Alang Alang Lebar* with 34.58km2, *Ilir Barat Satu* with 19.77km and *Gandus* with 68.78km2.

Figure 6. The result map of each of the 16 administrative areas in Palembang 2019
Map by Romdhoni, 2019

The size of Administrative was divided by the growth of Palembang City, where small administrative area were the older established areas and generally has a higher built urban density and growth concentration intensity, while the new administrative areas have lower urban density.

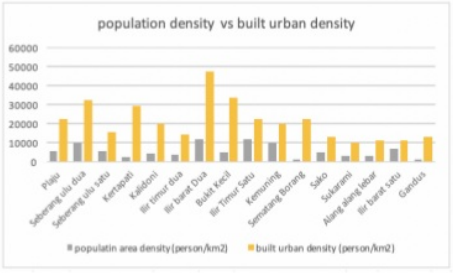

Figure 7. The population comparison between the 16 administrative areas population density vs urban built area density of Palembang
Graph by Romdhoni, 2019

From the research output, we could see the use of every administrative area

compared to the built and the unbuilt areas, and there are administrative areas that are densely built while there are others that show uneven growth by the comparison of built urban areas with the population census data. The most densely built administrative area is *Ilir Barat Dua*, with the contrast between population census and built urban area of 71,267 people with 1.49km2 showing the urban density of 47,673 people/km2. The lowest density in the administrative area is *Sukarami*, with a population of 155,590 people with the built urban area of 15.48km2 showing the urban density of 10,048 people/km2.

This result is different compared to the population density model provided by the census data by measuring the population with the administrative area shown on **Figure 8**. This method of comparing the census population with administrative data is only showing information of a general density but the flaw of this data that it does not show any information about the actual urban density of built urban areas.

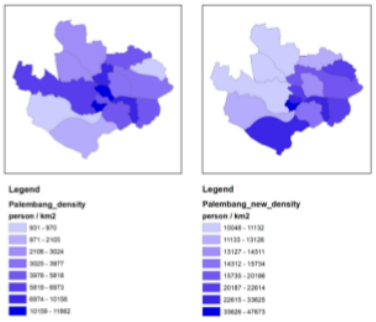

Figure 8. comparison between population density and built area density and Population ratio in Palembang
Map by Romdhoni, 2019

Figure 7 is showing the value of population density from the census data by dividing the population value with the administrative area size, compared to the urban built density by dividing the population value with the built area size. The result shows that there is a difference in the actual density of each area

Figure 9 shows the three classifications of urban growth in Palembang of Land-use cover maps from 2001,2007 and 2016 and detected the difference in built or changes from the non-built area with the built area. In 2001, the Palembang urban built area had 66.75km2, which increased to 99.02km2 in 2007 and 116.25km2 in 2016. This shows that the Urban built area has an annual increased of growth of approximately 2.83% in the past 15 years (2001-2016), with the rate of 3.3km2 every year.

$$\text{LUDI} = \frac{116.25 - 66.75}{116.25} \times 1/15 \times 100\%$$

$$= (49.5 / 116.25) \times 1/15 \times 100\%$$
$$= 0.425 / 15 \times 100\%$$
$$= 2.83\ \%$$

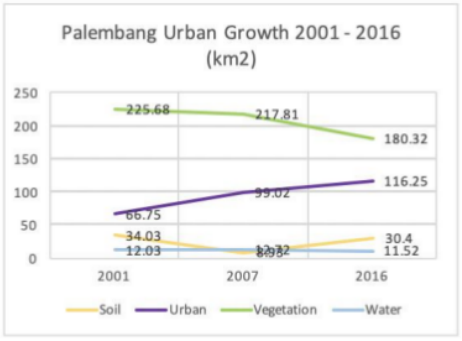

Figure 9. intensity of ULC / Urban Land cover in Palembang
Graph by Romdhoni, 2019

Palembang Natural Street and Growth Concentration

The urban growth in other Major Cities in South Asia and developing countries is caused by birth and migration. Among other countries in South Asia such as Sri Lanka (1.1%), Bangladesh (3.4%), Nepal (3.2%), Pakistan (3.3%), and India (2.4%) (Subasinghe et al., 2016). Palembang has shown significant urban growth of **2.83%** and can be considered as a rapidly growing metropolitan area in Indonesia. The population growth and urban-built area have been driven by urban migration to metropolitan areas, and it has been shown that the population growth in Palembang is also significantly high. Refering to **Figure 9** from the Palembang growth from 2001 to 2016, we could see that there is significant decline in area of vegetation after 2007 while the urban areas is showing a steady and consistant increase.

Urban growth and sprawl are moving simultaneously from the edge of the city and becoming a dominant form (Glaeser & Kahn, 2004). There have been changes in the Urban built area in Palembang where the mixture of housing is more derived to the outer part of the city, while commercial functions stayed at the center. The result of Urban expansion and the government plan of creating a satellite city in Palembang of Jakabaring Sport City has impacted the shape of the city. The green area has decreased rapidly in the city center, and the availability of mass transport such as the LRT / Light Rapid Transit in Palembang has created growth around the city centers. The growth of the city center should be balanced with the announced program from the government to develop a healthy and balanced growth in other administrative areas in Palembang.

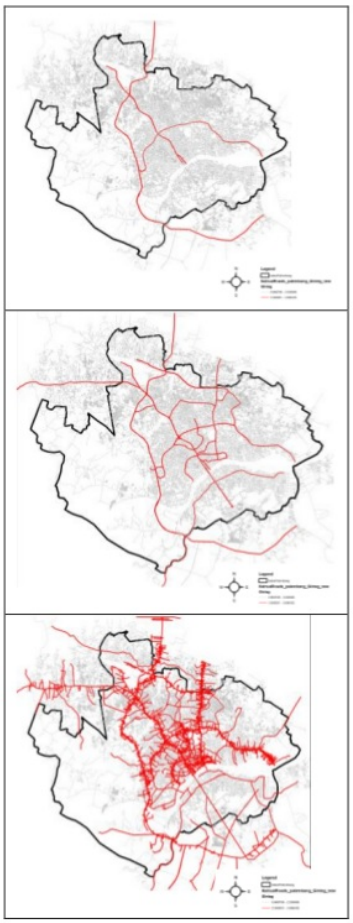

Figure 10.Global Integration of Palembang using two tone red-gray coloring
Map by Romdhoni, 2020

The condition of growth in Palembang is known as ribbon development, due to the existing of the main road i.e. *Jalan Sudirman*. Bhatta refers to Harvey about the concept of ribbon development as one of the major causes of urban sprawl (Bhatta, 2010). The ribbon development is the result of urban area fragmentation along the roads and the development of housing and commercial buildings as well as main transportation plan that causes a direct effect on the land-use planning creating a significant urban sprawl. From this urban growth density map,

we could analyze that Palembang could result in a similar problem created by accessibility feature, a needed balanced growth would be the solution for the future of Palembang.

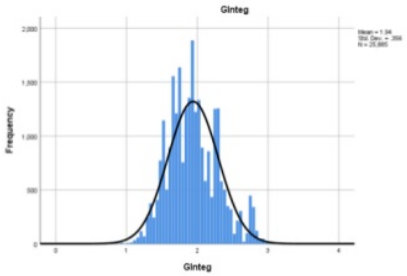

Figure 11. Global Integration histogram Palembang
Graph by Romdhoni, 2020

The global integration statistic value of the entire city of Palembang has a maximum value of 4.0 and a minimum value of 1.0 while the mean value of 1.94. the linear histogram in **Figure 11** indicate that the distribution of global integration in the city is evenly distributed.

The natural street analysis from the city of Palembang in **Figure 10** reveal the movement pattern of the street network in Palembang. The map is clustered into 3 different maps to show the difference of value in Global integration on the street network. This methods shows the hierarchy of street network and could also describe as the level of important street network in Palembang. The first map shows a red line with the Global integration value of more than 3.5, this map shows the 3 dominant street network in Palembang, with *Jalan Sudirman* as the primary road network that connect the northern part with the southern part of the city with two important ring road in the city. The second map shows a red line with the Global Integration value more than 3.0, this map is showing at least 15 important street network in the city, while the third map shows a red line with the Global Integration value of more than 2.5. In this third map it shows a large number of street network Palembang road network system.

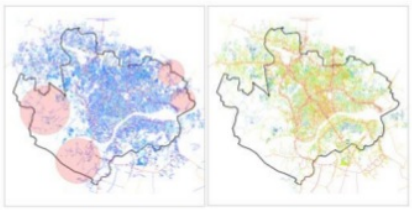

Figure 12. intensity of ULC / Urban Land cover in Palembang
Map by Romdhoni, 2020

The growth concentration of Palembang results show that parts of Gandus, Kertapati, sematang borang, and also kalidoni shown in **Figure 12** has patches of under developed parts. This highlighted area should have more attention and planning for future development in Palembang.

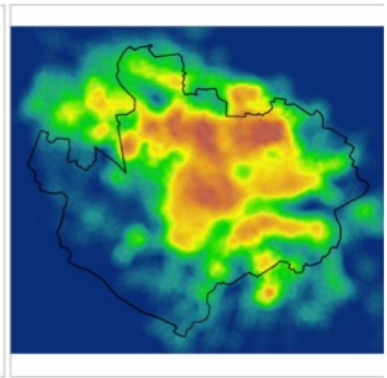

Figure 13. intensity of ULC / Urban Land cover density in Palembang
Map by Romdhoni, 2020

The linear density growth concentration in the city of Palembang in **Figure 13** reveal that the current condition of Palembang has become a nucleated city. The gradient of color with red and yellow color is showing a

high density of street network, and green and light blue is showing a low density of street network. The map is showing areas in Palembang with high intensity of density in the central area as well as the northern and north eastern part of the city.

The new bridges that connects the northern part and southern part of Palembang has contributed a significant value in the global integration value. The ampera bridge in picture 1 **Figure 14**, has been the main connecting bridge in Palembang that connects the northern part with the southern part of the city since 1966.

Figure 14. intensity of ULC / Urban Land cover in Palembang
Map by Romdhoni, 2020

The ampera bridge is an integral part of the Global integration for the city with the global integration value of 3.05. The new added bridge in picture 2 of **Figure 14**: Musi bridge IV that was newly used in 2019 has connected well the *pasar Kuto* area with the *kampong al-munawar* and creating integration between the *Kuto* and *Seberang Ulu* dua with the global integration value of 2.66
Also the new added bridge in picture 3 of **Figure 14**: *Musi* bridge VI that has just been opened for public in 2020 is connecting between the *Ki Gede Ing Suro* in kecamatan *Ilir Barat Satu* and kecamtan *Seberang Ulu satu* Palembang, with the global integration value of 2.83.

Conclusion

Urban growth in Palembang has shown that there is a high increase in number of urban density area from the year 2001-2007 that has created dispersions of urban pattern in the city. This urban growth has continued to evolve but creating a non-formal pattern that is linked to the center of the city. This type of growth of ribbon development could result in a disruptive pattern. In addition of the mass transport development in Palembang that is connected to the main road of the city could be proven as a way to better connect the city scape, however the multinucleated type of development will lead to a potential of urban sprawl and also causing environmental degradation in the future.

The multinucleated form of the city is still evolving and the uneven distribution of growth in the administrative area in Palembang could led to future harm for the city's evolution. The difference in city growth concentration and urban density will create different intensity in the city, where some parts of the city will be highly dense, while other parts will be under developed.

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and fruitfull discussions on spatial analysis methods and data resources.

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