

Analysis of Development Patterns of Built Land and Spatial Structure in Bandung City Using Landsat 8 Image Data

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ABSTRACT

The development of an urban area and the increasing totally of population growth greatly affect the need for land. To satisfy these needs, the land changes into built land which causes the density of an area. This study aims to analyze the development pattern of built land and the spatial structure of Bandung City. The data used are the 2015-2020 Landsat 8 time series imagery, the 2019 SPOT-6 imagery, and the administrative boundary map. The analytical methods used to identify and differentiate between built and non-built land classes are NDVI (Normalized Difference Vegetation Index) and the OTSU method with a threshold of 0.1. Based on the analysis, the results obtained are that the changes in the area of built and non-built land in 2015 amounted to 7,115.9 Ha and in 2017 it was 5,977.3 Ha and for 2 years the area decreased by 4%. Meanwhile, in 2017-2019 there was an increase of 2%, and in 2020 it decreased by 2% again. Based on the results of the analysis, the development pattern of land developed in the city of Bandung generally spreads from the city center to the suburbs, which are used as service / government centers, trade and service areas, and infrastructure. With this spreading pattern, the spatial structure is in the form of multiple nuclei or evenly distributed throughout the city of Bandung, where the City Center or CBD is used as a landmark for the surrounding areas. The high development pattern of built land has an impact on the surrounding environment, especially residential areas that have high building density causing the settlement area to become slum and reduce water catchment areas. The conclusion of this study is that the changes in the built-in land from 2015-2020 decreased by 3%, with the development pattern of the constructed land spreading out following the form of the road network, both arterial, collector and local roads.

Keywords: Developmental pattern, Built land, Spatial structure, Satellite image, Normalized difference vegetation index

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1. Introduction

The development of an urban area is increasing every year in the social, economic and cultural fields. In the development of a city, it is usually marked by a large increase in population (Dwiyanto et al, 2013). This will affect the need for land as a place to live or for other activities to increase while the availability of land is increasingly limited (Pangestu et al, 2016). With the limitation of the existing land area, it will have an impact on changing the pattern of urban development that leads to areas that have not been developed or to the suburbans in the city environment (Putra et al, 2016). The dynamics of land use that is used for settlements and infrastructure that support the activities of residents who live in urban areas.

Seeing the phenomenon of urban growth that continues to increase in Indonesia in the last few years, there will be a tendency to bring about the development of new urban areas around the city area. As it happened in the city of Bandung, which has a very dense population, both local residents and migrants who live in the area. The total population in Bandung City based on data from the Central Bureau of Statistics in 2018 is 2,503,708 people. Physical

developments in urban areas will accelerate and influence the process of forming the spatial structure of urban areas and land use (Sandri et al, 2016). From year to year the land use for built areas is increasing over time, this is due to the very rapid development of industrial activities, offices and services (Sitorus et al, 2012). Monitoring the development pattern of built land is very important to be done continuously to see the rate of growth and utilization. The development pattern of built land in the city of Bandung during the last 6 years has experienced a very significant development that affects the changes in the structure of the city.

Remote sensing technology is satellite data, has an important role in monitoring changes in the development patterns of built land in the city of Bandung. Landsat image data with a spatial resolution of 30 m in time series will be used to analyze the development of the built land pattern and the environment that affects it.

2. Methodology

This study about the analysis of the development pattern of built land on the spatial structure located in

Bandung City, West Java. The data used in this research is Landsat 8 satellite image data of 2015-2020 (LAPAN), SPOT 6 2019 imagery, Administrative Boundary (BIG).

The analytical methods used in this research are:

2.1. Data Processing Methods

Landsat 8 Sattelite imagery with a spatial resolution of 30 m which has 11 bands including Visible, Near Infrared (NIR), Short Wave Infrared (SWIR), Panchromatic and Thermal bands. Band number of 1,2,3,4,5,6,7 and 9 have a spatial resolution of 30 meters, band number 8 has a spatial resolution of 15 meters, while bands number of 10 and 11 have a spatial resolution of 100 meters. The processing data is used digital classification on the Google Earth Engine using the Otsu method to separate built and non-built land. In the calculation process, this method is used to determine the optimal threshold point for thresholding. This is done by minimizing the intraclass variance, or the same as maximizing the variance between classes from classes separated by a threshold. To separate these objects, the Otsu Thresholding Algorithm can be explained using the following formula:

$$\sigma^2 = P_{nv} (M_{nv}-M)^2 + P_v (M_v-M)^2$$

$$M = P_{nv} \cdot M_{nv} + P_v \cdot M_v$$

$$P_{nv} + P_v = 1$$

$$t^* = \text{Arg Max}_{a \leq t \leq b} \{ P_{nv} (M_{nv}-M)^2 + P_v (M_v-M)^2 \}$$

Note :

- σ : the variant within the vegetation and non-vegetation classes
- P_{nv} : probability of the pizel value to enter the non vegetation class
- P_v : probability of pixel value to enter vegetation class
- M_{nv} : average non-vegetation pixel value
- M : average NDVI image pixel value
- T^* : threshold value.

2.2. Analysis of the Identification of Built and Non-Built Lands

The process of identifying built and non-built land uses the NDVI (Normalized Difference Vegetation Index) method. NDVI is the NDVI is the most popular vegetation index used and can describe the condition of greenness, health and vegetation density (Trisakti et al., 2014). NDVI is basically a vegetation index in calculating how much absorption of solar radiation by plants, especially leaf parts (Rushayati et al., 2011). The vegetation index is a mathematical combination between the red band and the NIR band which has long been used as an indicator of the presence and condition of vegetation (Lillesand and Kiefer, 1997).

NDVI calculations are based on the principle that green plants grow very effectively by absorbing radiation in the visible light spectrum region (PAR or Photosynthetically Active Radiation), while green plants reflect radiation highly from the near infrared region (Ryan., 1997). NDVI values range between -1 (minus) to 1 (positive). The value that represents vegetation is in the range 0.1 to 0.7, if the NDVI value

is above this value indicates the health level of the vegetation cover is better (Prahasta., 2008 in Wass., 2010). Positive NDVI (+) values occur when vegetation reflects more radiation at near infrared wavelengths than visible light. Zero NDVI value (NDVI = 0) occurs when the reflected energy recorded by visible light wavelengths is the same as near infrared waves. Meanwhile, a negative NDVI (-) value occurs when the cloud surface, water, reflects more energy at visible light wavelengths than near infrared.

$$NDVI = \frac{(NIR - RED)}{NIR + RED}$$

2.3. Analysis of Change in Built and Non-Built Land

This analysis is carried out based on indications of spatial changes in built and non-built land over the last 6 years by monitoring its area and direction of development using remote sensing image data.

2.4. Analysis of Development Patterns of Built Land and Urban Spatial Structures

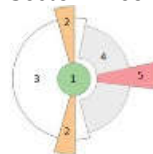
The development of a city that is easiest to see is by paying attention to the development of the physical condition of a city. The development pattern of developed land in urban areas can be divided into 3, are: a linear pattern with a shape following a road network, a pocket pattern with a clustered shape around the city center, a hierarchical pattern with an orderly shape and around the city center (Koestoer, 2001). Law on Number 26 of 2007 concerning spatial planning states that the spatial structure is the arrangement of settlement centers and a network of infrastructure and facilities that functions as a support for the community's socio-economic activities which hierarchically have functional relationships. According to (Yunus 2000) the theory of urban space structure becomes 3 (three) including:

1. Concentric Zone Theory



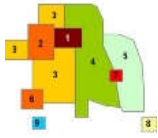
- Zone 1 : Central area of activity or CBD
- Zone 2 : transition (Trade zone switches to settlements)
- Zone 3 : Workers' / working class settlements
- Zone 4 : Middle class settlements
- Zone 5 : commuters (residential zone switches to agricultural zone)

2. Sector Theory and Multiple Nuclei Theory



- Zone 1 : Central area of activity or CBD
- Zone 2 : Wholesale & manufacturing area
- Zone 3 : low class settlements
- Zone 4 : Middle class settlements
- Zone 5 : Upper class settlement

3. Multiple Core Theory



- Zone 1: Central area of activity or CBD
- Zone 2: Wholesale & manufacturing area
- Zone 3: low class settlements
- Zone 4: Middle class settlements
- Zone 5: Upper class settlement
- Zone 6: Heavy Manufacturing Area
- Zone 7: areas outside the PDK
- Zone 8: Suburban Settlements
- Zone 9: Suburban industrial area

2.5. Impact of Built Land Development on the Settlement Environment

Descriptive analysis of spatial changes in Green Open Space that has changed the function of land into built land and other objects using remote sensing data.

3. Result and Discussion

3.1. Built Land Identification Analysis

Based on the results of the analysis, the identification of built land and non-built land is carried out using the Otsu method wherein the calculation process is carried out the separation between classes using the NDVI method.

```
//-----
//                               Fungsi Perhitungan Matematis
//-----
//cloud masking
function maskS2clouds(image) {
  var qa = image.select('QA60');

  // Bits 10 and 11 are clouds and cirrus, respectively.
  var cloudBitMask = 1 << 10;
  var cirrusBitMask = 1 << 11;

  // Both flags should be set to zero, indicating clear conditions.
  var mask = qa.bitwiseAnd(cloudBitMask).eq(0)
    .and(qa.bitwiseAnd(cirrusBitMask).eq(0));

  return image.updateMask(mask).divide(10000);
}

// Fungsi untuk menghitung indeks vegetasi
function addBands_Idx(image) { //S2
  var ndvi = image.normalizedDifference(['B8', 'B4']).rename('NDVI');
  var nbr = image.normalizedDifference(['B11', 'B8']).rename('NBR');
  var ndwi = image.normalizedDifference(['B3', 'B8']).rename('NDWI');
  return image.addBands(ndvi).addBands(nbr).addBands(ndwi).toFloat();
}

//-----
//                               Menentukan Indeks Lahan Terbuka dari Citra
//-----
// Memasukkan band indeks vegetasi pada citra dan pemotongan pada ROI
var S2_2019 = S2[0].filter(Th2019).filterBounds(roi)
  .map(maskS2clouds)
  .map(addBands_Idx);

var S2_2019_max=S2_2019.max();
var S2_2019_clip=S2_2019_max.clipToCollection(roi);

var S2_2019 = S2[0].filter(Th2019).filterBounds(roi)
  .map(maskS2clouds)
  .map(addBands_Idx);

var S2_2019_max=S2_2019.max();
var S2_2019_clip=S2_2019_max.clipToCollection(roi);

// Memanggil indeks Lahan Terbuka dari citra yang digunakan
var NBR2019 = S2_2019_clip.select('NBR'); // NBR
var permukiman_2019 = NBR2019.updateMask(NBR2019.gte(0.25));
```

Figure 1. The calculation process for the Otsu and NDVI methods identification of Built and Non-Built Land

The determination of the threshold by comparing several parameters of the threshold value so that it

can identify built land and non-built land. Based on the results of these calculations the threshold used is the NIR (8) and SWIR (11) bands on the Landsat 8 image with a threshold value of 0.1. The selection of the NIR / near infrared band has a wavelength of 0.85 - 0.89 UM with the use of pressing on the shoreline, while the SWIR band has a wavelength of 1.57-1.65 UM to differentiate soil water content and vegetation and penetrate thin clouds.

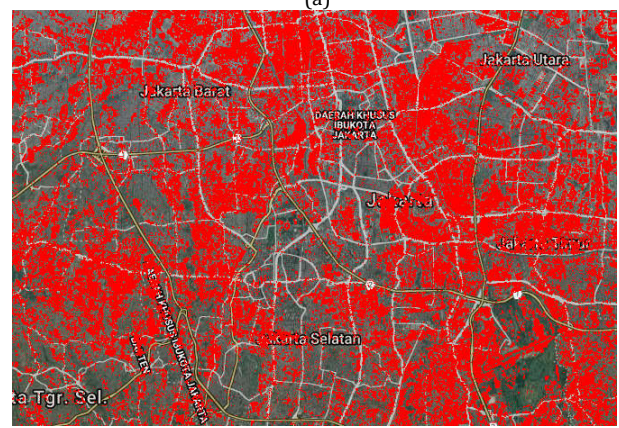
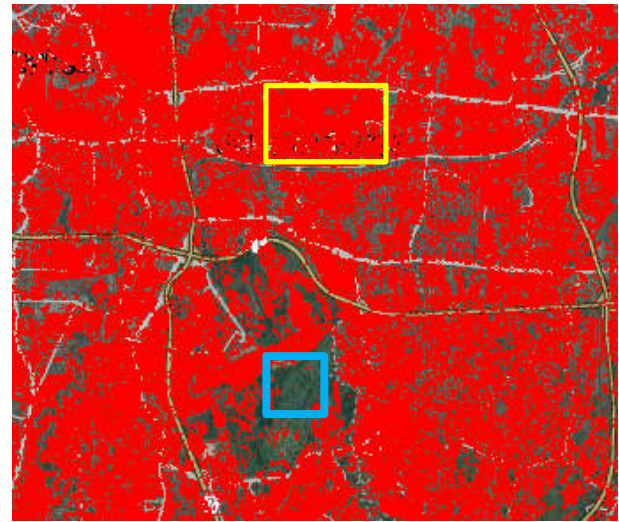


Figure 2. The threshold value of 0.1 (a) and the threshold value of 0.25 (b)

Based on Figure 2. Identification using a threshold of 0.1 is very clear the separation between built land and non-built land, while the threshold value of 0.25 identifies built land is still mixed with non built.

3.2. Analysis of Change in Built Land and Non-Built Land

Analysis of the identification of built land and non-built land resulted in the following areas:

The results of the calculation of the built land and non-built land area show that in 2015 the built area was 7,115.9 Ha and in 2017 it was 5,977.3 Ha so that the built land area decreased by 4%. Then in 2017-2019 the number of land developed was increased by 2%, and in 2020 it decreased by 2% again.

Table 1. Area of Built Land and Non-Built Land Using Landsat 8 Data

C	Large (Ha)					
	2015	2016	2017	2018	2019	2020
BL	7115,9	5977,3	6713,8	6586,7	7229,5	6191,1
NB	9773,1	10911,1	10174,6	10306,1	9658,7	10697,9

Source: Processing and Analysis Results

Information :

BL: Built Land NB: Non Built Land C: Class

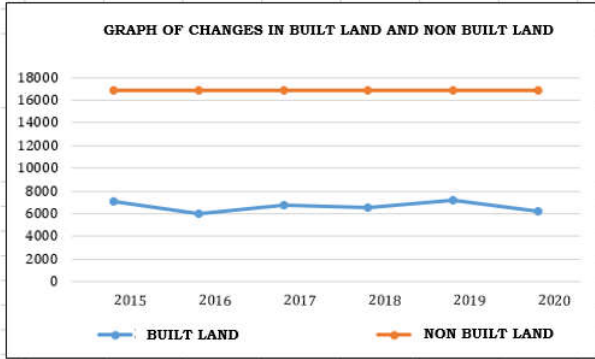


Figure 3. Graph of changes in built land and non-built land area in Bandung City

Based on Figure 3. It shows that during the 6 years starting from 2015-2020, the largest changes in built land occurred in Penyileukan and Gedebage Districts or heading west and south because the sub-district is an industrial and warehouse area. The development and process of spatial use in Bandung which is running fast, has implications for the need for spatial change. Currently, most of the land use is used for built land, namely 73.5% of which is in the city center, so that the physical development of the city has been directed towards the suburbans. The development and control of urban physical development must be in accordance with the RTRW 2011-2031 which has regulated the implementation of the urban spatial structure. Like as Gedebage District, because there are many industries and warehouses, the area will be used as a service center, trade, settlement and other activities that allow for a lot of development. Meanwhile, Cibiru District is still being maintained as a protected area for the area under it.

Visually, it can be seen that the built land in Bandung is very dense because from year to year there is an increase in population and other activities. However, after a quantitative statistical analysis based on remote sensing, it appears that the built land has an unnatural fluctuation, this possibility occurs due to a mixture analysis between built land and open land, especially agricultural fallow land. Changes in open / fallow agricultural land that are included in the identification of developed land in the following years can become vegetative land or vegetative paddy fields, which results in reduced area of built land. If it is correlated with decreasing vegetation land cover, the constructed land should have increased.

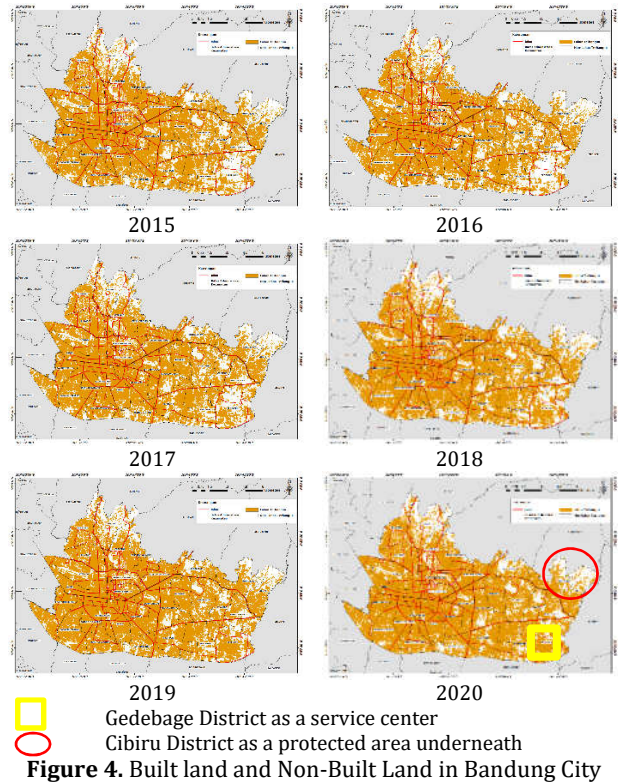


Figure 4. Built land and Non-Built Land in Bandung City

3.3. Analysis of Development Patterns of Built Land and Urban Spatial Structures

The development of built land patterns in Bandung City is still dominated by residential settlements (low, middle and upper class), either from the original inhabitants of Bandung City or commuting. Based on the results of the analysis using Landsat 8 data, it is known that the development pattern of built land generally spreads to form a linear pattern which is used as service / government centers, trade and service areas, provision of facilities and infrastructure (education, health, telecommunications, transportation, solid waste, water clean) and settlements. This can be seen in the results of the analysis Figure 5 using Landsat 8 imagery, the distribution pattern of residential areas from 2015-2020 is a clustered system. For industrial, trade and service areas, there are usually many new, irregular settlements that accommodate commuters working in the area.

The development pattern of built land usually follows the development of the road network both arterial roads, collector roads and neighborhood roads (Sandri et al., 2016). Activity centers are located on Jl. Diponegoro which is the center of government, trade and services as well as tourism.

The shape of the spatial structure in Bandung City is a multiple nuclei model or evenly distributed throughout the city. There are several important components in this model, are as a city center, an area for economic activity, a residential area and others. The city space structure in the form of multiple nuclei has a downtown area or CBD (Central Business district) which is located in the middle of the city center which functions as an area that provides infrastructure such as a center for transportation

facilities, a service center (government and banking) (Sandri et al., 2016).

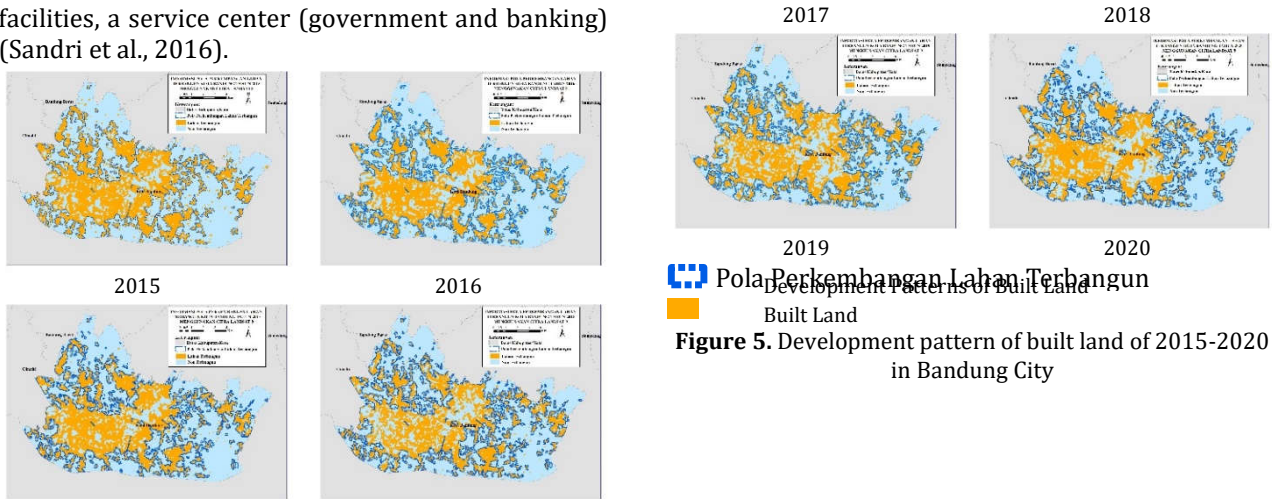


Figure 5. Development pattern of built land of 2015-2020 in Bandung City

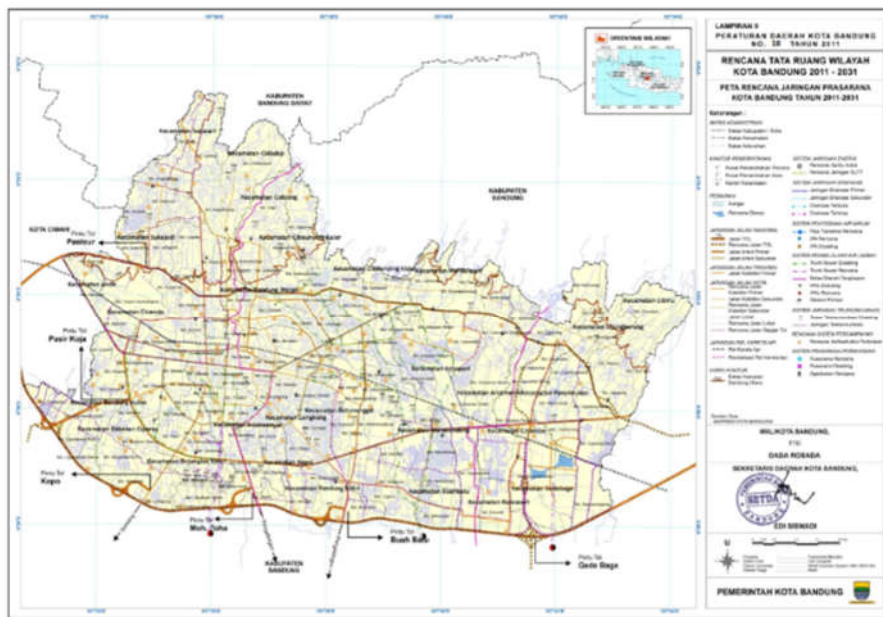


Figure 6. Road Network Pattern in Bandung City based on RTRW Data

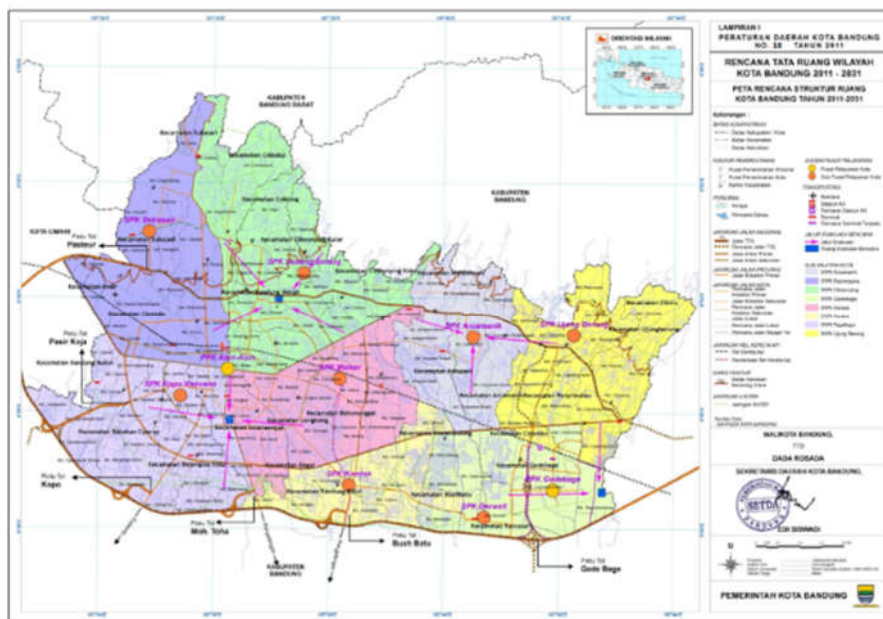


Figure 7. Spatial Structure in Bandung City based on RTRW Data

Based on Figure 7 and Figure 8, the 2011-2031 RTRW, the development and utilization of Bandung City space will shift service places in two sub-city centers, are the Sadangserang sub-city center and the Kopo Kencana sub-city center. The sub-center of Sadangserang city includes Coblong, Cibeunying Kaler, Cibeunying Kidul, Cidadap, Bandung Wetan and Sumur Bandung districts. Meanwhile, the sub-center of Kopo Kencana includes the Districts of Astananyar, Bojongloa Kaler, Bojongloa Kidul, Babakan Ciparay and Badung Kulon. The shift in services in the two sub-city centers is due to their location which is increasingly densely populated. In addition, access to locations is also less strategic, so people are looking for a place that is easier to reach.

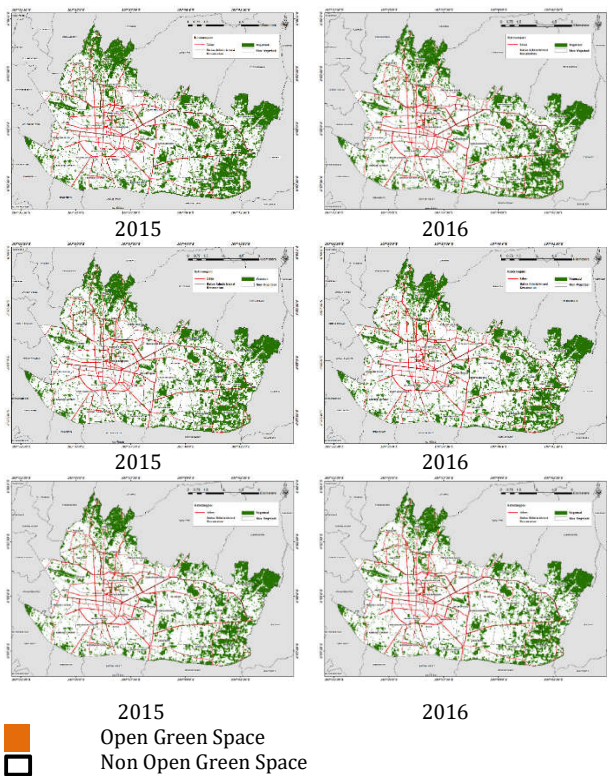


Figure 8. Spatial Structure of Bandung City

3.4. Impact of Built Land Development on the Settlement environment

Settlement environmental quality problems due to high building density, open green space and narrower parks so as to meet the supply of facilities and infrastructure (Yuliasuti et al, 2012).

Seeing the development of built land in Bandung city from year to year continues to experience a significant increase, it will have an impact on the environment where you live or settlement. Many built land was established to meet the needs of both trade and services, facilities and infrastructure to support the progress of an area regardless of the impact. The phenomenon that usually occurs is that there are lots of open green spaces that are used as public spaces where buildings are constructed. Even though this will have an impact on reducing water catchment areas. Another consequence arising from the increase in built-up land is the inconvenience of living quarters, which causes the environment to become slum area.

In Figure 8, it shows that in 2015-2020 there was a very significant decrease in the area of open green space in the city of Bandung where there was a lot of land conversion that was used for built land due to high urbanization and other commercial activities.

4. Conclusion

Built Land changes from 2015-2020 experienced a decrease of 3%, the largest increase in Gedebage District, which is a heavy industrial area that requires land as a residential area, trade and services, infrastructure and service centers.

The development pattern of built land spreads out following the form of the road network, both arterial, collector, and local roads. The form of the spatial structure of Bandung City is multiple nuclei or evenly distributed throughout the city of Bandung where the City Center or DBC is a landmark for the surrounding areas.

As a result of the increasing development of built land, it has an impact on the residential environment, including slum settlements which cause inconvenience to live in.

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