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Using Pixel-Based Image Classification to Identify City Structure Development in Balikpapan City, East Kalimantan

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***Abstract*— A city structure is a composition of forming a city. The shape of its city can characterize the development. City development must be sustainable, then the city structure formed must also support sustainable development. *Pixel-based image classification* is a method used in remote sensing to quickly and multi-temporally identify structures of development of the city. Balikpapan is a National Activity Center (PKN) that has a strategic location for national and international transport routes and, therefore, can accelerate the development of the city. The study aims to identify the development of city structures formed in Balikpapan from 2009, 2014, and 2019 by using *pixel-based image classification* and *overlay* analysis. The variables of this study are developed land, non-developed land, vegetation land, and water body. The study results show the development of the city structure by forming several core structures in Balikpapan, or called multi-nuclei, on city structure theory by Harris and Ullman in 1945. The built-up area dominates the development of the city structure, and development dominates from southern to eastern of Balikpapan City. The city center formed has a role as Central Business District (CBD), and the sub-city center created helps the city center to equalize sustainable development for a better future. The development of the city structure in Balikpapan provides direction to help adjust the city in the future.**

***Keywords*— Balikpapan; city structure; overlay; pixel-based; remote sensing.**

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I. INTRODUCTION

Remote sensing of images has been successfully applied in many fields, such as classification and change detection [1]. Through remote sensing data, it could be presenting a representation of the surface of the earth. Remote sensing data are raster images obtained from satellite sensors. One of the satellites that provide data is Landsat, released by the USGS (United States Geological Survey). Landsat images consist of Landsat 4, 5, 7, and 8. Each Landsat has different sensor components. For example, Landsat 5 has MSS and Thermal Sensors. Landsat 8 has more sensors, such as OLI, Panchromatic, Cirrus, and Thermal. The use of these sensors is relatively the same, especially for classification methods or thermal methods. Each Landsat image has a resolution of 30 m [2].

Remote sensing refers to the activities of recording, observing, and perceiving (sensing) objects or events in faraway (remote) places. In remote sensing, the sensors are not in direct contact with the objects or events being observed [3]. Land-cover mapping using satellite or airborne imagery has increased exponentially over the past decades, partially due to improved data availability and accessibility [4].

Remote sensing image classification is the process that converts remotely sensed imagery to usable products [5]. The remote sensing application that many researchers often use is the earth's surface classification method. One classification technique used is pixel-based classification; this technique works on each pixel and also extracts information from remote sensing data only on spectral details [6]. This pixel-based classification is a fast and easy classification technique for multi-temporal analysis. The supervised classification technique on the pixel-based classification method is widely used. This technique uses several pixel samples, which are used as examples to give value to the pixel as a whole. This method can be used to monitor the development of city structures that occur on the surface of the earth.

Urban spatial structure is described as an abstract or generalized definition of geographic space distribution. Understanding urban spatial structure has compelling significance in the development of planning strategies and policymaking supports for building livable, vibrant, high-density cities, which can be measured in the context of functions and activities. Planners and decision-makers should

understand the formation of urban spatial structures in shaping cities. Urban spatial structure exerts a powerful influence on individual daily life, social equity, economic growth, and sustainable development [7]. To further reveal the evolution of regional spatial structure and enhance regional development efficiency, more studies of spatial interaction in the urban agglomeration area are urgently needed [8].

Urban development is a kind of humanistic phenomenon inherent in the earth's surface, appearing along with economic development and population growth, rapid urban expansion means that cities are now changing large amounts of agricultural land and other vegetation areas [9]. Development Balikpapan has been developed in the south and east of the city. Airport development has an impact on the development of the southern region, which is connected with the city center. For example, in the eastern part, development is focused on building roads that connect the city center with several sub-centers of the city [10]. The city has increasingly expanded the conversion of vegetation land to non-vegetation both by the city government and the community itself, resulting in changes in land use and has implications for changes in the structure of urban space [11].

Previous research on the comparison between pixel-based and object-based classification explains that the two methods produce similar data and are very suitable for analyzing changes that occur on the surface of the earth [12]. The pixel-based classification is effectively used to temporarily monitor changes in the earth's surface, such as landslides mapping [13]. In 2013, a study explained that pixel-based and object-based classification could be used in various fields, including for land use and land cover classifications and detecting changes [14]. And in 2015, research on land cover change detection in 43 countries used remote sensing to facilitate the identification of land cover change [15].

Research conducted in the city of Bengaluru, India, explains the remote sensing classification accuracy for landscape structures, proving that the accuracy of these methods provides the highest value for determining changes in landscape structures [16]. In 2019, research in the city of Leipzig, German land cover change dynamics with a multi-temporal remote sensing approach that shows this approach allowed vegetation density and vegetation changes to be detected both spatially and temporally for highly diverse urban structures [17].

The use of the pixel-based classification is located in Balikpapan City, East Kalimantan. Balikpapan City is a National Activity Center (Pusat Kegiatan Nasional/PKN) based on PP number 26 of 2008 [18], its strategic location as a national and international transportation lane makes Balikpapan City has the potential for rapid development of the city structure. This study aims to identify growth in the city structure in 2009, 2014, and 2019. The results of this study are expected to be used as a reference for the development of Balikpapan City structures in the future that support sustainable city development.

II. Material and Method

A. Study Area

The research area is Balikpapan City. Balikpapan City, as a National Activity Center (PKN) and has a strategic location as a national and international transportation lane, makes this city have the potential for rapid development in the formed city structure. The development of the city structure can be identified from the development of land cover and signs of urban development. The research area can be seen in Figure 1.

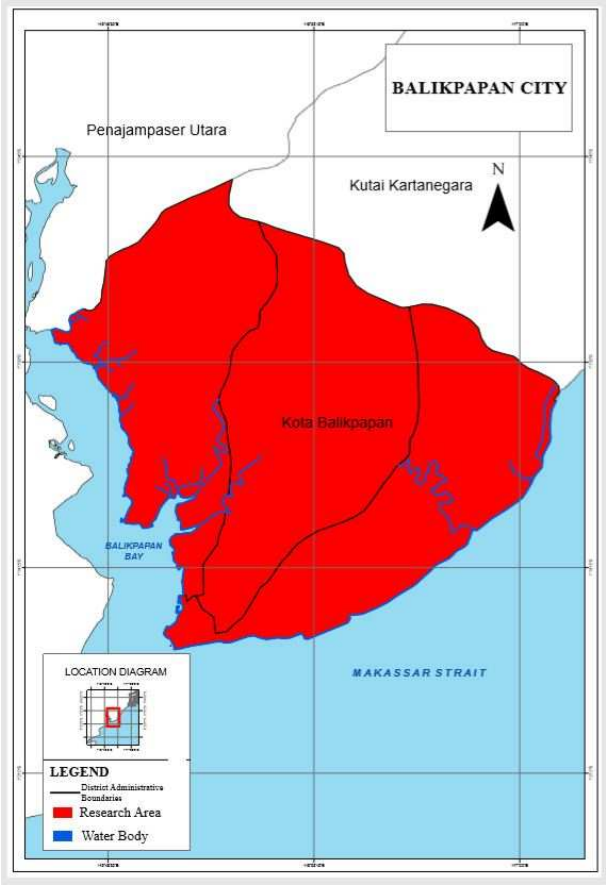

Fig. 1 Research Area

B. Data Source

This study obtained temporal coverage Landsat 5 TM and Landsat-8 OLI/TRIS images from 2009, 2014, and 2019 with a standard spatial resolution 30 x 30 m from the US Geological Surveys (USGS) archive (http://earthexplorer.usgs.gov/). The study area is located in a southern Landsat image (path 116 rows 61). To minimize the effect of atmospheric noise on image classification was limited to 30%. The collected images contained a cloud cover of 30% (2009), 20% (2014), and 10% (2019).

C. Image Processing

The UTM 50S map projection was used for the image as it is used in Balikpapan City. Then according to Jia et al. [19], radiance calibration was performed by converting the digital number (DN) values to surface spectral reflectance and removal of atmospheric effect (atmospheric correction) with the darkest pixel subtraction techniques using ENVI version 5.1.

1) Radiometric Calibration Process: The atmospheric effects of dispersed aerosol particles and atmospheric gases that traveled all through from the earth's surface [20]. It means even though the atmospheric and radiometric effects have no significant influence over the classified image for LULC changes detection, it is necessarily required to eliminate their effects for investigating unforeseen variations in green cover [21]. In this technique, the digital number (DN) values are converted to the radiance unit for Landsat. A radiometric correction was carried out on the Landsat image and carried out to correct the pixel values in the image that were not following the actual reflection value of the object due to atmospheric disturbance at the time of recording [22]. The formula does radiometric correction:

$$\rho\lambda' = M\rho\, Qcal + A\rho \quad (1)$$

$$\boldsymbol{\rho\lambda} = \frac{\boldsymbol{\rho\lambda'}}{\boldsymbol{\cos(\theta Sz)}} = \frac{\boldsymbol{\rho\lambda'}}{\boldsymbol{\sin(\theta SE)}} \quad (2)$$

2) Supervised Image Classification: Then, after radiometric correction, the Supervised classification process is carried out. This supervised classification involves intensive analysis, which shows the classification process by identifying objects in the image (training area). So sampling needs to be done by considering the spectral pattern at each particular wavelength so that a functional reference area is obtained to represent an object [23].

Traditionally, supervised classification is cluster analysis, or clustering involves grouping a set of objects. Hence, the objects in the same group are more similar to each other than those in other groups. Several algorithms have been developed based on neural networks, decision trees, k-nearest neighbors, naïve Bayes, support vector machines, and extreme learning machines to address multi-class classification problems [24].

A natural color composite from the Landsat 8 OLI/TRIS bands B7, B4, and B2 was associated with red, green, and blue (RGB). The sample polygons were created based on visual interpretation of the image to recognize the land cover, feature classes. In this study, reference points were selected in each feature class from Google Earth as the base map. Google Earth offers high-resolution satellite imagery on different dates and times for many places.

The variables used in this study are built-up land, non-built-up land, vegetation, and water bodies that are monitored in Landsat 5 in 2009, Landsat 8 in 2014, and 2019. The development of land cover in 2009, 2014, and 2019 became a reference for developing the Balikpapan city structure. Figure 2 shows the flow of thought of this study.

In determining the development of the city structure formed, it can be seen from the changes in land cover that occur. Pixel-based classification is generally done by grouping pixels into classes that have been determined based on the average and spectral value variants of each pixel [1].

In this study, the pixel-based classification method used is guided classification with the maximum likelihood algorithm in ENVI 5.1 software. In brief, after creating training samples for each class of land cover, a maximum likelihood algorithm is run, which will automatically classify land cover based on land cover sample training [25].

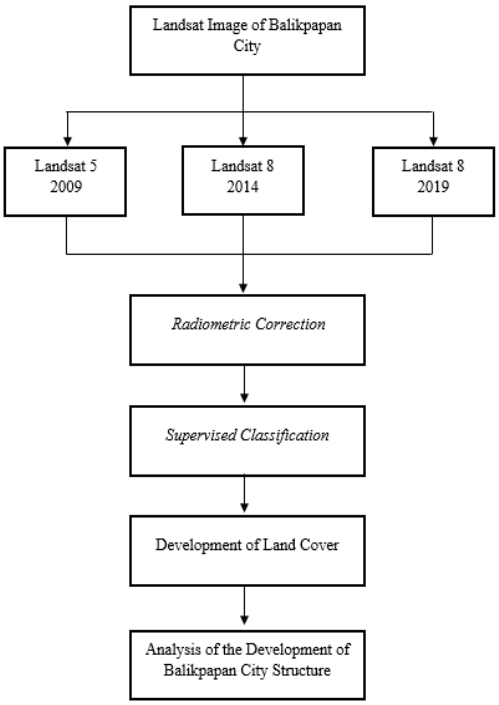

Fig. 2 Research Flow

III. Results and Discussion

A. Land Cover Change

Based on the results of data processing, in 2009, it was seen that the built-up area in Balikpapan was not under the definition in the southern part of the city of Balikpapan. Figure 3 shows a non-built-up area that spreads south to the east of the city of Balikpapan. The vegetation area is still focused on the north side, and it is caused by the uneven ground conditions in the northern region.

In 2014, development increasingly dominated the southern to eastern parts of the city of Balikpapan; quite a lot of functions shifted from vegetation land to built-up land (see Figure 4). Transfer of services also occurred from vegetation land that turned into non-built-up land in the central and northern side of the town of Balikpapan. The non-built-up land is added to the area that has a data surface making development possible.

In 2019, the dominant change occurred by shifting the function of open land to built land (see Figure 5). Changes also occur in vegetation land that is transformed into developed land or public land, vegetation land that changes a lot is found on the eastern side of the city of Balikpapan. For the south side, development looks evenly distributed to the point of being stable.

On the land cover, it can be seen that land cover changes only occur in the south to the east of the city. For the north, it remains the dominant area for vegetation; this is due to the uneven surface of the northern area, making the area difficult for development. Meanwhile, the city's southern and eastern regions tend to be more flat so that growth can be done.

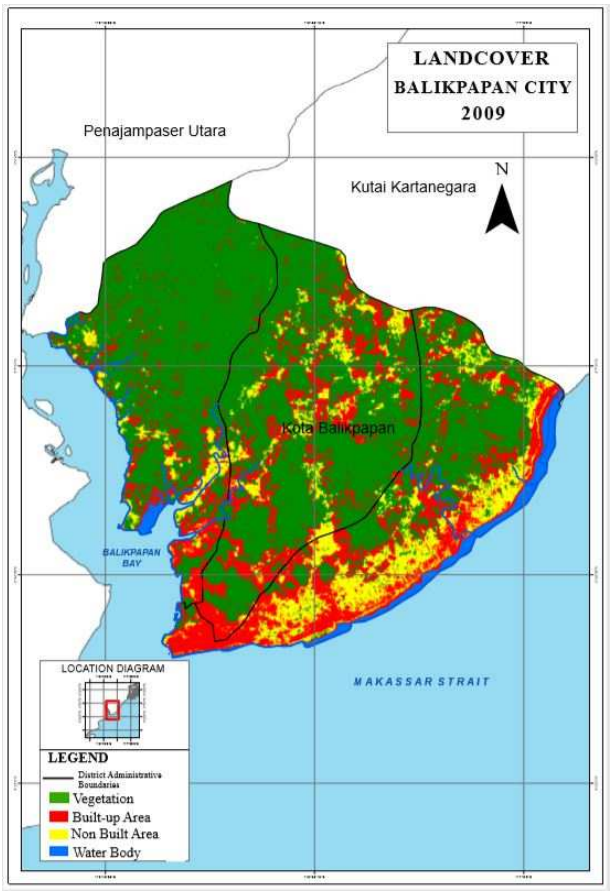

Fig. 3 Land Cover Map 2009

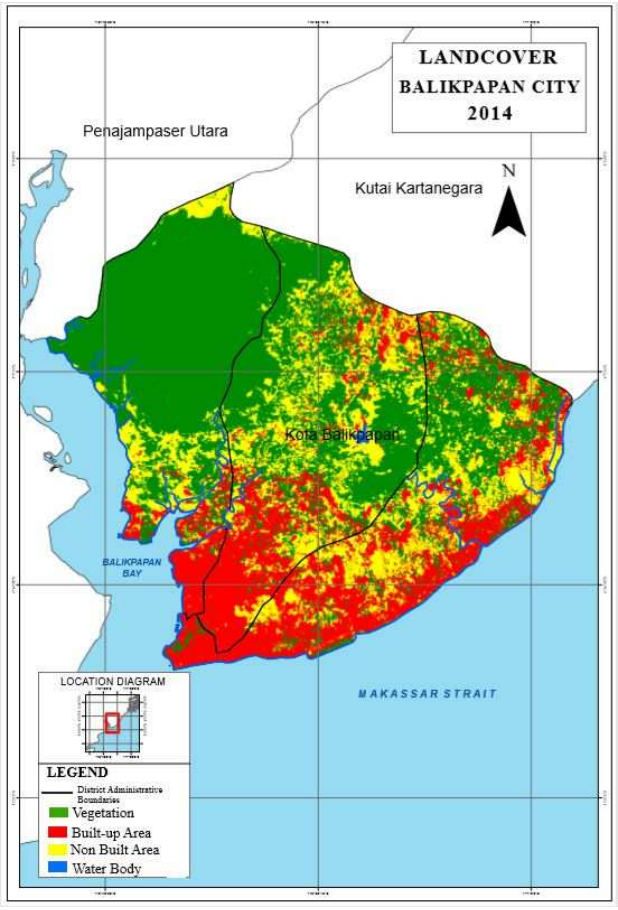

Fig. 4 Land Cover Map 2014

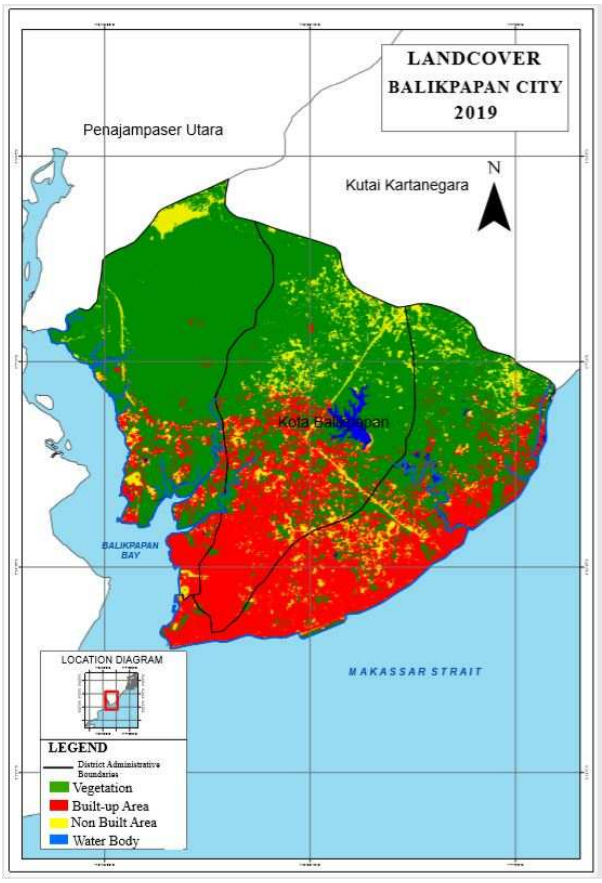

Fig. 5 Land Cover Map 2019

Figures 3, 4, and 5 show changes in land cover in the City of Balikpapan, which is dominated by changes in land cover built by 26.7% or around 3,108 hectares. Still, the reduced open land and vegetation lands were 1,397 hectares and 1,195 hectares, respectively. There are changes in other land covers, such as open land, which increased considerably to 12,287 hectares in 2014 and then decreased to 4,475 hectares in 2019. Then there was a change in vegetation land of 3.7% or around 1,195 hectares. These land cover changes can be seen in Figure 6.

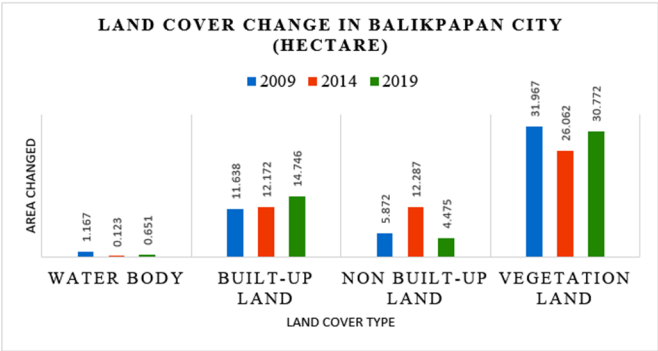

Fig. 6 Land Cover Change Diagram

B. City Structure Development

Based on data processing, the results show that in 2009 Balikpapan City had one city center located on the south side of the city (see Figure 7). The city center is directly adjacent to the sea, facilitating trade or transportation links between islands or between provinces. Besides being a city center location directly nearby to the sea, the city center location also

has a flat surface so that the area can be built with additional facilities to support the city's needs and can be accessed easily.

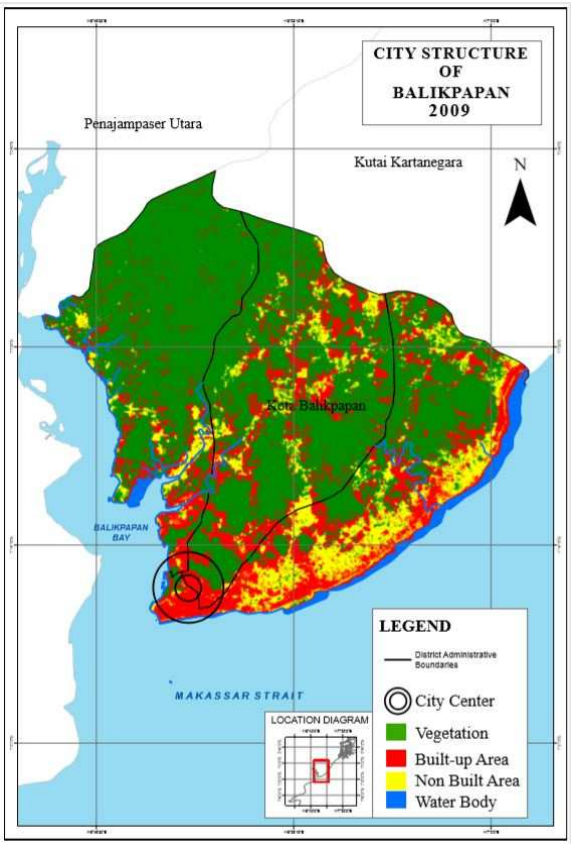

Fig. 7 City Structure Map 2009

The city center was also formed based on existing built-up land, indicating that the location is a strategic location for the commercial or residential area. As a city center, this location functions as the center of city government, trade, and services on a regional scale. The built-up land in the southern part of the city indicates that city development starts from that location and meets the criteria to become a city center in terms of accessibility or strategic position.

In 2014, there was a development of the city structure of Balikpapan (see Figure 8). Construction of the built land begins with the addition of 2 sub-centers on the south and east sides of the city of Balikpapan. The sub-city center is helping to level out construction or level facilities in the city of Balikpapan. Two city centers are formed based on the built-up land that exists in relatively dense locations and can represent the surrounding location. The city center serves as a city-scale trade and service center and the city-scale education service center.

There was a structural development in Balikpapan City wherein 2009, and there was one city center. In 2014 with the increase of built-up land, the sub-city center emerged as a support for the city center, 2019. As more land is developed, it also supports the city center as well as support for districts around the City of Balikpapan. Increased sub-city center locations are considered to be able to reach surrounding places to support the needs of the city. They can also facilitate the construction of city facilities while having easy access because the location of the sub-city center is on a flat surface. Also, the development of a city structure can be influenced by the activities of its residents.

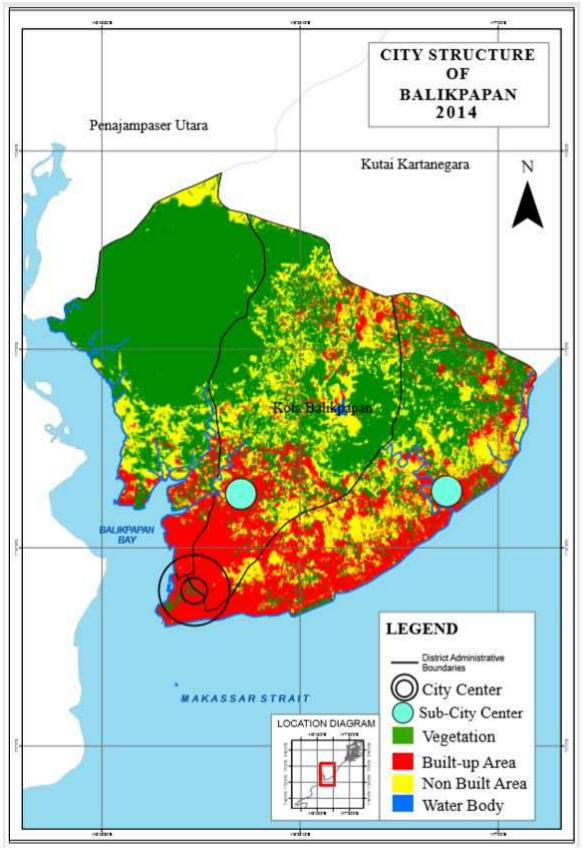

Fig. 8 City Structure Map 2014

The use of supervised pixel-based shows that this method can be used to analyze the shape of city structures using satellite imagery and is an effective and efficient method when compared to non-pixel-based methods [11]. The city structure formed in 2019 is a double core structure with one city center and several sub-centers as its support, so not only Balikpapan City but the surrounding districts can also depend on Balikpapan City (see Figure 9). The city center is the Central Business District (CBD) with priority in the leading economic sector in the City of Balikpapan. It has a residential zone around it, while other sub-city centers support the city center so that development and services are evenly distributed to the entire city of Balikpapan. If adjusted to the theory, the City of Balikpapan uses a multi nuclei pattern as a form of city structure.

The multi nuclei theory was put forward by Harris and Ullman in 1945 in their article “The Nature of Cities’. This model describes the layout of a city or land use in groups form linked with specific activities or functions. Multinuclear is created based on development that starts from a center and becomes a complex form. This sophisticated form will encourage the formation of new urban centers and develop according to functional land-use and make the city structure in the way of multi nuclei [26]. This theory explains that the function of the city center as CBD (Central Business District), and the city center is part of the support of the city center. Settlements surround each city center, and the closest settlements to the center are low-class settlements. The

farthest settlements within the scope of the city center is a high-class settlement [27].

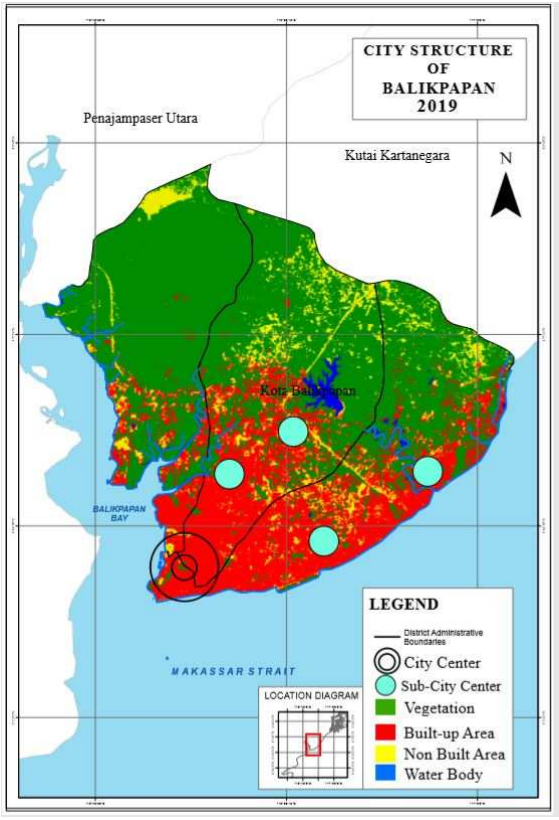

Fig. 9 City Structure Map 2019

Based on the Balikpapan City structure plan designed by the government, several city structure classifications have been established: the city center in the south of Balikpapan, which is used as the center of government, trade, and services on a city scale. The sub-city center is divided into two functions: a trade center for assistance and a regional-scale education center and a second function, namely as a city-scale trade and agro-service and a city-scale education service center. The sub-city center is spread in the middle of the city to the east [18]. The shape of the city structure is under the Balikpapan City Structure Plan for 2012 - 2032 designed by the government. The government's plan has become a reference for carrying out development in Balikpapan and is sustainable [18].

Balikpapan City, which is the National Activity Center (PKN), implements development sustainably and equitably. The city center bordering the sea facilitates inter-island or inter-island or inter-city/provincial trade and sub-centers, making development in the city of Balikpapan evenly distributed. It also affects the development of the Balikpapan City structure that was formed. In 2009, there was only one activity center in the southern part of Balikpapan City. Furthermore, in 2014 changes occurred with the increase in sub-centers of city activities. Subsequently, in 2019, the sub-center will increase by one more, covering all businesses in the area around the City of Balikpapan.

Based on the Central Statistics Agency (BPS), Balikpapan City said that in 2009, Balikpapan had a population of 515,529 people. In 2014, the population increased to 599,685 people, and in 2019 there was an increase in population to 645,727 people [28]. The more population or higher population density, the need for new housing areas to accommodate the entire population, causing more residential areas.

Government data can be a reference that the community can influence the city's development both in terms of land cover and city structure. As the population increases, more urban services are needed. The city government must meet the needs of its population from various sectors, such as the economy, health, housing, or education sector must be met by the city for the welfare of the city community.

IV. Conclusion

Based on the Balikpapan City structure 2019 (see figure 9) and the Balikpapan city structure plan, the development that occurred has followed or is almost below the Balikpapan city development plan. The Balikpapan Government has built a city center, which acts as an environmental center with more equitable development functions in the form of sub-scale trade and service centers, district-scale health service centers, and district-scale education centers [18].

With the city structure plan with three compositions of the city center, sub-city center, and environmental center, the city of Balikpapan can create sustainable and equitable development. The functions of each center and sub-city center start at the international, regional, and district levels. Then the city structure plan can reflect or optimize the city of Balikpapan as a National Activity Center (PKN).

The study results showed that pixel-based classification methods could be used to identify changes in land cover and the development of urban structures that occur in Balikpapan. The increase of built-up land dominated the difference in land cover that occurred. The reduction in the two areas is due to land conversion to built-up land. The structure of the developing Balikpapan city is influenced by population activity and in line with the increasing population. The downtown area must be expanded or form a city center to facilitate services for urban communities in any region.

The strategic location of Balikpapan City, which is a cross between national and international transportation lines and its role as the National Activity Center (Pusat Kegiatan Nasional/PKN), is one of the influential factors in land cover changes that occur. With the existence of the city center and sub-city center, it is expected to be able to serve the entire community equally and create sustainable development in the city of Balikpapan. It is also hoped that the City of Balikpapan can optimize its role in the economic sector to reflect its position as the National Activity Center (PKN).

Nomenclature

$\rho\lambda'$	Reflectant ToA which has not been corrected to the sun's angle.
$M\rho$	Scale factor (Band-specific multiplicative rescaling factor).
Qcal	Enhancer factor (Band-specific additive rescaling factor).
$A\rho$	Pixel value (DN)
λ	TOA reflectance corrected sun angle
θSE	Sun's elevation angle (local sun elevation angle).
θSZ	Zenith solar angle (90°- θSE)

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