Spatial Pattern Changing Analysis of Built-up Due to The New Era of Aerotropolis in Kulon Progo, D.I. Yogyakarta

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Abstract. Built-up is artificial land use representing urban-oriented activities according to the sector developed in the aerotropolis, the development concept of city activity centered on the globally networked economy’s airport. The growth of unplanned built-up often caused environmental deterioration. Therefore, the impact of the emerging of a new growth center to the growth characteristic of the built-up requires to be analyzed. This research aimed to examine the growth and spatial distribution characteristics of built-up to mitigate the undesirable impact on the environment in the early phase of aerotropolis in Kulon Progo. The growth was analyzed using the spatial intersection of land use/land cover. The distribution orientation growth was carried out by weighted mean center and spatial standard deviational ellipse. The results demonstrate that annual growth of built-up increased from 55.35 ha per year in 2010-2015 to 69.83 ha per year in 2015-2020. Dryland agriculture was the most land use converted to built-up after aerotropolis era. The direction of built-up growth also shifted from northwest to southwest, and the distance between the airport and the mean center was getting closer. Therefore, land use planning policy need to refer to this pattern changing to preserve environmental sustainability while achieving economic growth.

1. Introduction
The emergence of a new airport significantly affects the regional economic growth of Kulon Progo. The Gross Domestic Regional Product (GDRP), the economic indicator of growth, grew by 5.96% in 2017 but grew rapidly by 10.84% in 2018. This percentage exceeds the national average growth of 5.17% [1] and the province of 6.20% at the exact time [2]. The construction sector had the most significant contribution, about 19%, to the GDRP in 2019. The multiplier effect of airport construction indicates the rapid GDRP growth in Kulon Progo. However, further analysis is required to prove whether the construction sector growth is only contributed by airport construction or because of a multiplier effect that affects the growth of other sectors. The multiplier effect will generate activity and cause consumption of land that accommodates urban-oriented activities in aerotropolis. This phenomenon will lead to the spatial pattern changing that triggered by new growth center.

The function of airports in the 21st century has developed beyond transportation infrastructure. It also provides rules as an economic hub [3]. The concept of an aerotropolis has evolved as an urban area with structure, infrastructure, and economic activity centered on the airport [3]. Kulon Progo decreed as the
airport construction site with the aerotropolis development concept in Indonesia’s national strategic planning [4,5]. The airport creates inter-regional connectivity, new growth centers in regional constellations, opens accessibility [6], and a meeting point that creates added value for the region [7]. In addition, airport development contributes to regional development by creating jobs [6,8,9], stimulating investment, and creating business opportunities [3]. Incheon International Airport, which has been developed with a concept of aerotropolis, advanced air traffic to 71.2 million passengers, 2.76 million tonnes of cargo in 2019, and offered more than 700 store brands that create US$ 2.4 billion in sales [10]. Other cities successfully implemented aerotropolis are Amsterdam Schiphol, Paris Charles de Gaulle, Dubai, Zhengzhou, and Memphis [11].

The effect of the new airport in generating activity requires to be observed spatially, not confined only to the macro contributions in GDRP. The spatial effect of airport development can be observed from the urban growth [12]. Urban growth is characterized by an increase in the built-up [13,14] and the dynamics of land conversion [15]. In addition, the effect can be observed from the change in the spatial direction of the built-up due to a new growth center emerging in the south. The shifted land value causes the direction change in spatial orientation from a predominantly rural area to an urban area based on the economic land rent perspective [16]. Therefore, dynamic growth and spatial directional change of built-up need to be carried out to investigate the effect of development perspective-changing. This research aims to examine the growth and the spatial distribution characteristics of built-up in Kulon Progo to mitigate undesirable environmental impacts in the early phase of aerotropolis. The changing of spatial pattern characteristics, especially built-up, is essential to conduct official land use planning because the growth of unplanned built-up often causes environmental deterioration [17]. Thus, land-use policies in Kulon Progo can be formulated appropriately based on the dynamics of changes.

2. Method

2.1. Study Area

Kulon Progo Regency was selected as the study area where Yogyakarta International Airport as a new growth center was built. Kulon Progo is located at 7°38'42"-7°59'3" South Latitude and 110°1'37"-110°16'26" East Longitude. It is one of the regions in the Special Province of Yogyakarta consists of twelve sub-district shown in figure 1.

Figure 1. Study Area.
The study selected 2010, 2015, and 2020 points of time. The year 2010-2015 was the period before the aerotropolis era. The year 2015-2020 was the aerotropolis development plan period that started with the issuing of the Location Determination Permit Number 68/KEP/2015 on March 31st by the Governor of Yogyakarta, Sri Sultan Hamengkubuwono X. The construction and operation of the airport occurred during that period. Therefore, both periods served as benchmarks to observe the dynamic changing orientation of built-up growth in Kulon Progo.

2.2. Data
The study used multitemporal image data from Landsat 7 in 2010 and Landsat 8 in 2015 and 2020 with 30 m spatial resolution. Data was obtained from https://earthexplorer.usgs.gov. In addition, the ground checks were conducted on December 3rd-10th, 2020.

2.3. Analysis
Image data were processed using the supervised classification method with a maximum likelihood to obtain six types of LULC in the Kulon Progo Regency, including wetland agriculture, dryland agriculture, built-up, forests, mixed plantation, and water bodies. Supervised classification serves classification land use/land cover using pixel categorized supervision by image analyst to the computer algorithm [18]. Pixel categorization was done by creating training area and labeled it into the most closely resembles land cover class. This method produces the better results of classification for the diversity of land use instead of unsupervised [19]. Maximum likelihood seeks to find the class of land use for the pixel most likely class category or class with the highest probability value have been threshold set by analyst according to the created training area [18]. Then, the annual growth of the built-up was calculated in two different development periods. The first period was 2010-2015, which represented the period before the construction of the new airport. The second one was 2015-2020. The spatial intersection conducted to obtain the area change. The mean of area change in every period was calculated to observe the annual growth.

Furthermore, the directional growth of the built-up was analyzed using the spatial weighted mean center. Weighted mean center calculates the center of spatial distribution of feature [20] similarly to the mean of the sample using specific weight for each feature. The feature in this research is the polygon of built-up. A similar method has been used to analyze the direction of mosques growth [21] and shopping center growth [22]. The following is the equation to determine the spatial weighted mean center.

\[
\bar{X} = \frac{\sum_{i=1}^{n} z_iX_i}{\sum_{i=1}^{n} z_i}, \quad \bar{Y} = \frac{\sum_{i=1}^{n} z_iY_i}{\sum_{i=1}^{n} z_i}
\]  

\(X_i, Y_i\) are the geographical coordinate of polygon centroid \(i\). The weight of every polygon resulted from the area of the polygon that initialized with \(z_i\). \(\bar{X}, \bar{Y}\) is the spatial mean center. This equation was used in the three-point time of the built-up to obtain the growth direction.

Spatial distribution orientation changing was identified using spatial standard deviational ellipse. This analysis served the geographical dispersion of the data [20,23]. The component of the standard deviational ellipse defined by four parameters: (1) center gained from mean center, (2) major axis, (3) minor axis, and (4) rotation angle [21] illustrated in figure 2. The major and minor axis gained from the calculation of deviations from the mean center. The rotation angle is also a function of the deviations in the x-axis and y-axis from the mean center.
There were three steps to obtain the standard deviational ellipse [22]. First, translate the coordinate of all polygon into equation 2 to gain the rotation angle of the ellipse, θ.

\[
\theta = \arctan \left\{ \frac{\sum (x_i - \bar{x})^2 - \sum (y_i - \bar{y})^2 + \left[ \frac{\sum (x_i - \bar{x})^2 - \sum (y_i - \bar{y})^2}{4\sum (x_i - \bar{x})^2 - \sum (y_i - \bar{y})^2} \right]^2}{2} \right\}
\]  

Second, compute the standard deviation of x and y axes using the equation below:

\[
S_x = \sqrt{\frac{\sum (X_i' \cos \theta - Y_i' \sin \theta)^2}{n}}, \quad S_y = \sqrt{\frac{\sum (X_i' \sin \theta - Y_i' \cos \theta)^2}{n}}
\]

\(S_x, S_y\) are the dispersion indices for x and y axes direction, respectively. \(X_i' = X_i - \bar{X}\) and \(Y_i' = Y_i - \bar{Y}\). The standard deviational ellipse of both the x (minor axis) and y (major axis) obtained from equation 4.

\[
\text{Length}_x = 2S_x, \text{Length}_y = 2S_y
\]

This research conducted the first-dimensional standard deviational ellipse. It means that the data covered by the ellipse is approaching 68% [23].

3. Result and Discussion
The analysis shows that the built-up has been growing through the period spatially distributed indicated in figure 3. The yellow polygon indicates built-up denser, especially in the south region in recent years. In addition, the calculation of built-up growth excluded the airport area to determine the multiplier effect. In 2010, built-up in Kulon Progo was 985.91 ha and increased to 1,262.70 ha in 2015. Meanwhile, it grew to 1,611.86 ha in 2020. The annual growth rate of the built-up also increased from the first period to the second period. The annual built-up growth rate in the 2010-2015 period was 55.35 ha year\(^{-1}\). However, in the 2015-2020 period, it increased to 69.83 ha year\(^{-1}\). The result denotes that the airport stimulates activities from a built-up growth perspective as a land-use representing urban activities [24]. The construction of the airport creates a climate that encourages the growth of built-up. It means that the increase in GDRP in Kulon Progo is not only caused by the construction of a new airport. This condition is in accordance with the positive response of business actors, especially in the construction sector, who assess that Kulon Progo has the highest readiness compared to other regions in Yogyakarta in capturing economic opportunities [25].
Figure 3. Spatial distribution of built-up in (a) 2010, (b) 2015, and (c) 2020.

In addition, agriculture was the most land use converted to built-up. However, the two periods have different characteristics of change. In the 2010-2015 period, wetland agriculture fields became the most widely converted to the built-up shown in figure 4. Meanwhile, in the 2015-2020 period, dryland agriculture was the most widely converted to built-up shown in figure 5. Changes in land use characteristics converted from the majority of wetland agriculture to dryland agriculture fields in the second period are influenced by new growth centers in the south area of Kulon Progo. The growth center is an area that is experiencing more massive land conversion dynamics than other areas. The existence of the airport also contributes to the development of the southern causeway or JILS. Its causes the strategic value in the southern part of Kulon Progo to increase. The increasing strategic land value can enhance land rent based on the locational rent aspect. Agricultural land is a land use with a high probability of being converted into other land uses because it has a relatively lower land rent [26,27]. As a result, many dryland agriculture in the southern part has changed. Meanwhile, wetland agriculture is spread south to north of Kulon Progo Regency, as shown in figure 6.
The emergence of a new growth center in the southern part of Kulon Progo affects the change in the orientation of the built-up. This change can be seen based on the mean center of built-up in 2010, 2015, and 2020 conceived with red, yellow, and green dots, respectively, in figure 7. In the 2010-2015 period, the mean center shifted to the northwest, marked by a red dot of the 2010 mean center towards the yellow dot of 2015. There were changes in the direction of built-up growth towards the southwest in the 2015-2020 period. In addition, the distance between the airport and the mean center of built-up was getting closer. The distance between the airport and mean center from 2010, 2015, 2020 were 13.48 km, 12.91 km, and 11.66 km, respectively. It proves that built-up is growing closer to the new growth center.

The standard deviational ellipse at each point of the year in figure 7 shows that the built-up in 2015 was further spread out. However, in 2020, the distribution of built-up was narrower. This spatial distributional change indicates the built-up’s growth trend is increasingly concentrated in the second period. It is in accordance with the aerotropolis concept that accommodates a new paradigm in the city called new urbanism. This paradigm leads the development towards a compact city. This concept provides high-density development to overcome sprawl that consumes mass land. Compact cities are characterized by high density, efforts to protect agricultural land, and efficient use of existing land [28]. This is realized through Transit-Oriented Development (TOD). TOD emphasizes the use of built-environment factors such as mixed-use, density, and walkability, to maximize the benefits of improved transit accessibility [29]. Aerotropolis carries the TOD concept with the airport as its main center.

The overall direction of the built-up is always oriented northeast to southwest through time, and the centers are primarily concentrated in the central urban areas. However, the inclination angle in 2020 is different from the other. It tends to follow the arterial road pattern shown in figure 7 with the blue line. The arterial roads connect Kulon Progo with other regions. This indicates that the aerotropolis era
strengthens the interaction and makes broader accessibility between the region. The enhancement of accessibility captured as an economic opportunity. This causes a shifted land rent in the strategic area. Thus, the built-up concentrated in that location.

The construction of a new airport in Kulon Progo indicates a multiplier effect in terms of growth and changes in built-up orientation. Land use planning policy need to refer to this orientation pattern changing to realize appropriate planning. This analysis requires to be complemented by land-use predictions. It provides a possible future growth trajectory in the area under certain scenarios. Land suitability analysis is also required to evaluate which areas can be used for economic activities and which areas should be protected. Regional development planning can realize sustainability.

4. Conclusion
The construction of a new airport in Kulon Progo has a multiplier effect on the growth and direction changes of the built-up perspective. The emergence of new growth centers had increased the annual growth rate of built-up in the early phase of the aerotropolis era. The direction of built-up growth in the aerotropolis period changed to the southwest, approaching a new growth center. This also had an impact on changes in land conversion patterns. This spatial pattern of change proves that there was an effect of aerotropolis on the development in the region by the growth of built-up that accommodate activities. Aerotropolis in Kulon Progo shows a positive impact in the early phase by triggering activities spatially. This research provides a methodology to measure the effect of the emergence of new growth center spatially instead of the common indicator like GDRP. This research is an essential input in projecting future built-up. Thus, land-use policies must be adaptive by considering the existing changes to accommodate economic growth while preserving environmental sustainability.

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