

**Original Article**

## Spatial Variability of Land Use Changes Due to JJLS (Southern Cross Road Network) Development in Kulon Progo Regency in 2016, 2020, and 2024

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**ABSTRACT**

The construction of the JJLS (Southern Cross Road Network) project in Kulon Progo Regency passes through Kapanewon Galur, Panjatan, Wates, and Temon to connect the Provinces of DIY and Central Java. The development of JJLS infrastructure can lead to the development of residential land and other functional buildings in the surrounding areas (Hendry, 2021). This study attempts to determine changes in land use variability due to the construction of JJLS in Kulon Progo Regency. Based on this information, changes in land use that occur intensively in certain areas can be monitored and detected early, so that appropriate policies can be formulated to prevent uncontrolled changes in land use. The research method used in this study is the interpretation of sentinel 2 imagery, which is then overlaid with a land use map to determine land changes that occurred in 2016, 2020 and 2024. Statistical analysis was carried out to determine the effect of JJLS development on land use changes in Kulon Progo Regency, especially in the sub-districts through which JJLS passes. The results of the study showed that there were significant changes in land use in the range of 2016, 2020 and 2024. Based on the results of the RCI calculation in 2016 to 2020, the lowest RCI value is 0,2917 and the highest value is 3,156. While the RCI value for 2020 to 2024 had the lowest value of 0.3862 and the highest was 2,1791. Based on the RCI value, it is divided into 3 classes, low, medium, and high, in order to represent the intensity of change in each village. Based on the results of statistical calculations, it can be concluded that there is a strong influence between the JJLS variable and the growth of built-up area in the research location.

**KEYWORDS**

Land use and land cover change, JJLS, RCI, Kulon Progo

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## INTRODUCTION

Referring to the Village Development Index in 2021, the coastal area of Kulon Progo Regency is included in the underdeveloped areas that require special attention in the form of access to market facilities to support socio-cultural, economic, tourism, and environmental sustainability activities. Part of the effort to overcome the inequality that occurs is through infrastructure development in the form of a road network.

Kulon Progo Regency has a road segment passed by the Southern Cross Road Network (JJLS) which passes through Kapanewon Galur, Kapanewon Panjatan, Kapanewon Wates, and Kapanewon Temon to connect the Provinces of DIY and Central Java. The Decree of the Governor of DIY No. 118/KEP/2016 states that the JJLS as a national road aims to develop border and underdeveloped areas by developing a road network system that can connect urban and rural activity centers. The development of JJLS infrastructure can lead to the development of residential land and other functional buildings in the surrounding areas (Hendry, 2021). The development of the road network will also have an impact on the expansion of built-up area and affect the development of the city structure (Bintoro, 2008). The development of the area due to the construction of the JJLS is marked by a drastic increase in land use conversion, which was originally non-built-up area, into built-up area.

Research conducted by Ramadhan (2019) found a change of built-up area in Kulon Progo Regency in 2011 by 6,7% or 4.427 Ha and experienced a significant increase in 2018 to 8.401 Ha or 12,85% of the total area. Sufiyana (2018) explained that there was a change in the perspective of the community in Kulon Progo, which initially considered land productivity for rural areas, now shifting to urban areas that consider the strategic location of a land. This change is usually accompanied by a decrease in the area of agricultural land to built-up area (Wahyudi, 2019). Therefore, monitoring is needed to control the trend of land use changes. If these conditions are neglected, it will endanger the ecosystem's sustainability (Pratomoatmojo, 2014; Dinda, 2022; Sudjana, 2024). In addition, coastal area is susceptible to shoreline recession caused by abrasion (Tilova, 2024).

The study of land use change and its spatial variability has gained considerable attention, especially in areas experiencing rapid infrastructure development. Various research has highlighted that the construction of large-scale transportation network often leads to

significant land use transformations specifically in urban land and its spatial distribution (Ahasan, R., & Güneralp, B, 2022).

The Southern Cross Road Network (JJLS), as part of Indonesia's strategic infrastructure plan, is expected to influence spatial patterns of land use due to increased accessibility, urban expansion, and shifting socio-economic dynamics. Remote sensing and GIS-based approaches have become the state-of-the-art methods in detecting and analyzing land use and land cover changes over time. The use of multi-temporal satellite imagery, such as Sentinel-2 with its high spatial and temporal resolution, has enabled researchers to map land use transitions with improved accuracy and consistency (Phiri et al., 2020). Furthermore, Sentinel-2 imagery plays a key role in supporting informed decision-making processes related to land use change (Arfa, A., & Minaci, M, 2024). In particular, supervised classification methods combined with accuracy assessment metrics such as Overall Accuracy and the Kappa Coefficient are widely applied to land cover interpretations (Rwanga, SS & Ndambuki, JM, 2017). Supervised classification offers the advantage of controlling class definitions by utilizing known sample inputs (Richards, J.A. 2022).

Recent studies in Indonesia have demonstrated that infrastructure development often causes spatially heterogeneous land use changes, including the conversion of agricultural land to settlements, commercial zones, or bare land, with variations across different zones depending on proximity to the infrastructure corridor (Handayani, et al, 2018; Surya, et al, 2020; Salim & Faoziyah, 2022, Pravitasari, et al, 2021). The expansion of built-up areas prior to agricultural or bare land is the defining feature of urban growth dynamics (Dehghani, 2025). However, studies focusing specifically on the spatial variability of land use changes caused by the JJLS development remain limited. This research addresses that gap by integrating multi-temporal remote sensing data and spatial analysis techniques to assess the dynamics of land use change in Kulon Progo Regency.

This study offers a novelty to the research on land use changes due to the development of the Southern Cross Road Network (JJLS), specifically focusing on the spatial variability in Kulon Progo Regency. The analysis is conducted across three different time in 2016 (before construction), 2020 (during construction), and 2024 (after construction) providing a perspective that is often lacking in similar studies.

This research conducted in several key aspects. First, the temporal aspect allows for a comparative assessment of land use dynamics before, during, and after the JJLS development, enabling the identification of both immediate and evolving impacts on the environment. Second, the study employs high-resolution Sentinel-2 satellite imagery, which facilitates more precise and detailed land use classification across different time periods. Third, this research emphasizes the spatial variability and distribution of those changes, revealing the heterogeneous nature of development

impacts across different zones, such as urban fringes, agricultural lands, and coastal areas.

This study attempts to examine the influence of JJLS development on spatial variability of land use changes in Kulon Progo Regency. Based on this information, changes in land use that occur intensively in certain areas can be monitored and detected early. The findings of this research can be applied for regional planning and environmental policies for sustainable land management due to the development of the Southern Cross Road Network (JJLS).

## METHOD

### Research Location

This research was conducted in several sub-districts (including Kapanewon Galur, Panjatan, Wates and Temon) in Kulon Progo that is passed through by the Southern Cross Road Network (JJLS), which has 25,60 km segment. The coordinates are located between 390000 - 417000 mT and 9117300 - 9117300 mU. The research

area is 145,04 km<sup>2</sup>. Determination of the research location is carried out based on the distinct feature of each sub-districts such as a new airport (NYIA) located in Kapanewon Temon, Kapanewon Wates whis is city center of Kulon Progo, Kapanewon Panjatan which has the largest agricultural area in Kulon Progo, and Kapanewon Galur is the corridor that connects Bantul and Kulon Progo Regency. The following is a map of the research location stated in Figure 1.

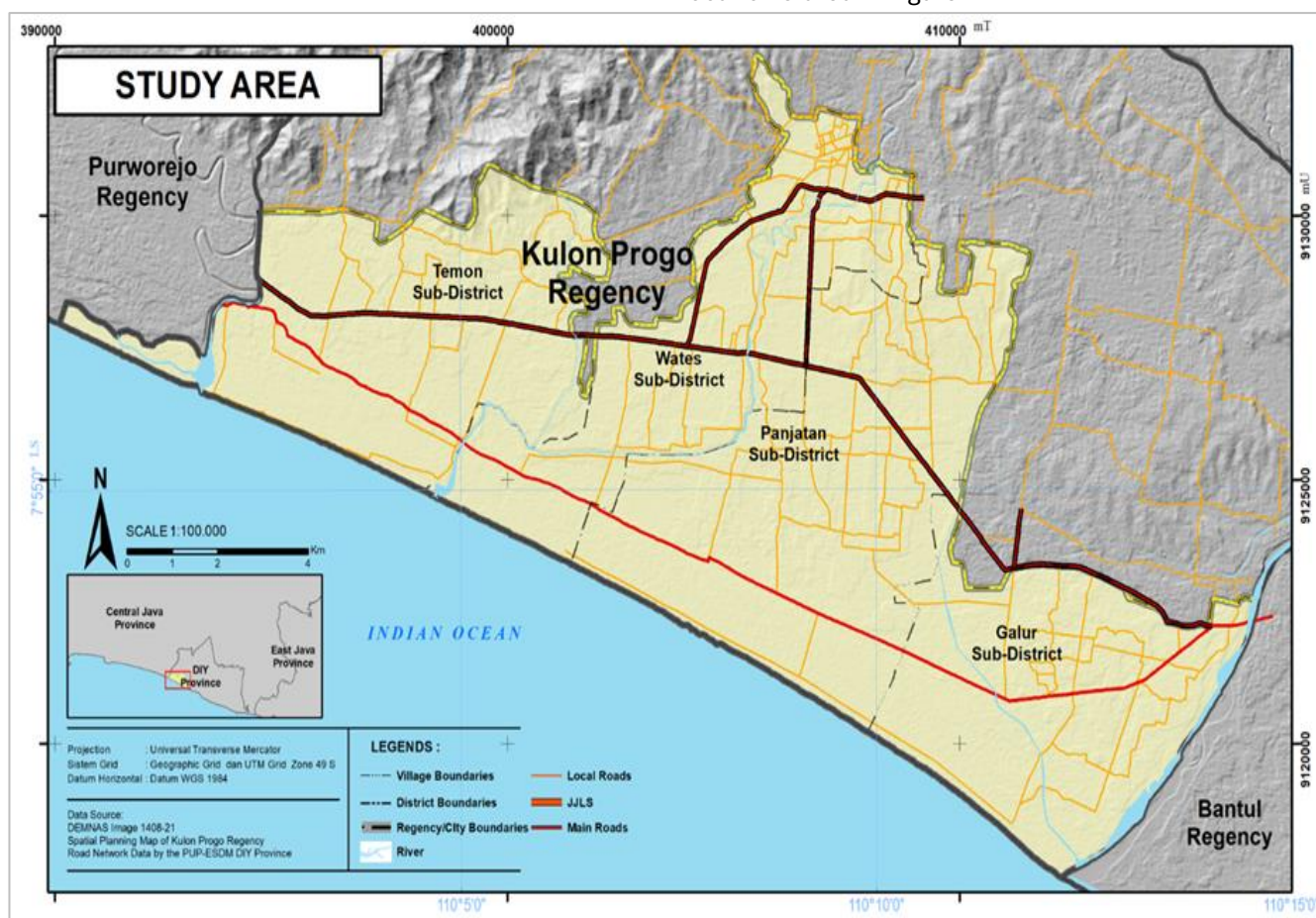


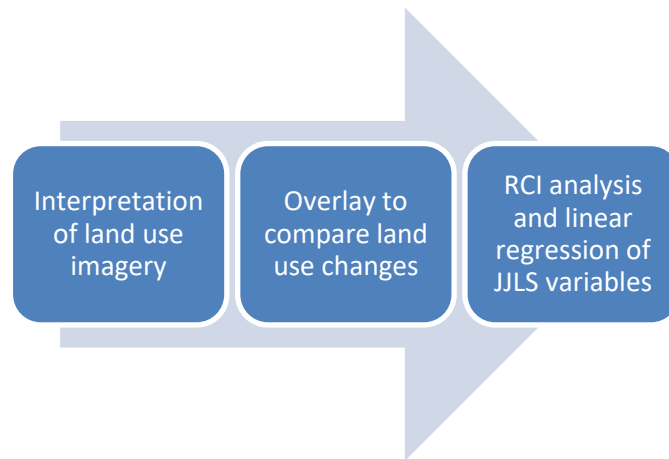
Figure 1. Research Location Ma

## Research Approach

The research approach used in this study is a quantitative approach in the form of remote sensing analysis and statistical calculations.

## Research Procedures

In general, this research was conducted in several stages, as shown in Figure 2.



## Figure 2. Research Procedure

### Data Collection Instruments

Land cover information is obtained from Sentinel 2 imagery which has a resolution of 10 m. Land cover information obtained from Sentinel 2 imagery has a spatial resolution of 10 m. Spatial resolution affects the level of detail and accuracy of mapping information (Lillesand et al., 2015). Based on the LAPAN remote sensing data criteria (2015), the output from Sentinel imagery is included in the high spatial resolution criteria. According to PP No. 21 of 2021 concerning the Implementation of Spatial Planning, data with high spatial resolution can be used for the study of Regency Spatial Planning with a scale of 1: 50.000 or 1: 25.000 (BSNI, 2014).

The classification scheme used refers to the remote sensing-based land cover classification class compiled by LAPAN (2014). Table 1 is the land cover class classification system used in this study.

**Table 1.** Land Cover Map Classification Scheme

|                   | Land Cover Classification   |
|-------------------|-----------------------------|
| Non-built-up area | Body of water               |
|                   | Fishpond/ pond              |
|                   | Rice field farming          |
|                   | Dry land farming            |
|                   | Plantation                  |
|                   | Bare land                   |
|                   | Beach border                |
| Built-up area     | Urban Settlement            |
|                   | Rural Settlement            |
|                   | Industry, trade and tourism |
|                   | YIA Airport                 |

## Data analysis

### 1. Interpretation of Sentinel imagery

The composite combination method of visible channels (4,3,2), false color (8,11,4), NDVI (Normalized Difference Vegetation Index) index transformation results, and NDWI (Normalized Difference Water Index) index transformation results were used for visual interpretation in this study (ESA, 2015; Hakim, 2018; Sarun, 2018; Pamungkas, 2023). Research conducted by Putri (2020), compared the level of land use mapping accuracy of visual interpretation classification methods, supervised multispectral classification (maximum

likelihood), and unsupervised multispectral classification (K-Means). Her research showed that the visual interpretation method had the highest level of accuracy with an accuracy level of 92,5%, while the accuracy of the maximum likelihood and K-Means methods were 62.5% and 40%, respectively. Therefore, this study uses visual image interpretation to obtain land cover information.

Furthermore, information related to the distribution of land use changes is obtained through overlay analysis using two land cover maps in different years. Based on the overlay results, the location of land use changes along with their area will be known. Analysis

of land cover changes in the coastal area of Kulon Progo Regency was carried out on the 2016-2020 land cover map and the 2020-2024 land cover map. The analysis of land use changes will focus on the area and growth and conversion of land that was originally non-built-up area into built-up area that occurred in the study area.

## 2. Statistical Calculations

Statistical analysis is used to obtain the value of land use change from non-built up to built-up area. The statistical analysis used in this study is RCI analysis (Relative Covertion Index Analysis). RCI is a comparison between the proportion of land change in each village (RDK), with the proportion of land change in the entire study area (RTK). RDK is a comparison between the change of non-built-up area to built-up area (ADK) with the total area of non-built-up area in each village (AD). While RTK is a comparison between the area of change of non-built-up area to built-up area with the area of non-built-up area in the entire study area.

The RCI value can be used to indicate the intensity of the magnitude of changes in built-up area in each village. If the RCI value is 1, then the intensity of land changes in a village is the same as the changes in the entire study area. However, if it is more than 1, then the intensity of changes in built-up area in a village is higher than the intensity of changes in the study area. The formula for determining RCI in Susilo (2016) is as follows:

$$RCI = \frac{Rdk}{Rtk}; Rdk = \frac{Adk}{Ad}; Rtk = \frac{Atk}{At}$$

Meanwhile, to determine the relationship or influence between changes in land cover in this study using linear regression analysis with the help of SPSS software. Linear regression analysis is a statistical method that can be used to determine the relationship and influence of independent variables on dependent variables. Dependent variables are variables that experience the impact of the value of the independent variable, while independent variables are variables that have independent properties and their values are not affected by other variables because they generally will have an influence on the dependent variable.

The independent variable in this study is the distance of land cover change to JJLS. The value of the independent variable is obtained by using a road buffer (JJLS) with a buffer distance of 200m, 400m, 600m, and so on to find out how far JJLS affects the development of built-up area. The magnitude of the influence of the

independent variable or JJLS on the dependent variable or the area of land use change can be known through the results of the significance value (Sig.), the correlation coefficient value (R) and the determination coefficient value (R squared).

The Sig. value indicates whether there is a correlation in the two variables used or not. If the Sig. value is less than 0,05 (<0,05) then there is an influence given by the independent variable to the dependent variable or the two variables are correlated. The R value has a range of values between 0 and 1, a value of 0 indicates that the relationship between JJLS and land cover change is very weak or even no relationship. However, if the coefficient value near 1 then the relationship between JJLS and land cover change is very close (Alipbeki, 2024). Meanwhile, the coefficient of determination (R squared) value explains how large a percentage is given by the independent variable to be able to explain or even predict the value of the dependent variable (Santoso, 2018).

## RESULTS AND DISCUSSION

### Land Cover Identification

Land cover identification was conducted using a remote sensing-based land cover classification system with various resolution levels, developed by the National Institute of Aeronautics and Space (LAPAN) in 2014. The interpretation of land cover utilized Sentinel-2 satellite imagery from the acquisition years 2016, 2020, and 2024, obtained from the Copernicus Data Space Ecosystem <https://browser.dataspace.copernicus.eu/>.

According to the remote sensing data criteria established by the Center for Remote Sensing Utilization (Pusfatja LAPAN) in 2015, Sentinel-2 imagery is classified as high spatial resolution imagery. This classification supports its suitability for accurate visual interpretation and reliable land cover classification. The use of Sentinel imagery provides high visual interpretation accuracy and enables precise land cover classification. In general, land cover classification is divided into vegetation areas, bare land, built-up land, and water bodies. (Saputra, 2023; Indriana, 2024). This makes the resulting information highly suitable for supporting spatial planning and regional development efforts.

The interpreted land cover map for the year 2024 is used as the reference for evaluating the accuracy of interpretation. Accuracy assessment could not be conducted for the 2016 and 2020 land cover maps due to

limitations in field information and the unavailability of relevant informants to verify historical land cover conditions. Therefore, the 2024 land cover map serves as the basis for determining the interpretation accuracy level, as the field data collection was carried out in the same year as the imagery acquisition.

The accuracy assessment of land cover interpretation in the coastal area of Kulon Progo Regency in 2024 is presented in Table 3. Referring to the table, the land cover interpretation using Sentinel-2 imagery achieved an overall accuracy of 92.7% and a Kappa coefficient of 0.907.

**Table 2.** Results of Land Cover Accuracy Test in the Research Area in 2024

| Confusion Matrix        | Field Observation |                                                                                                                                                                                                             |       |       |      |      |       |       |      |      |      |      | Row Totals (Xi) | User Accuracy (%) | Comission Error (%)  | Xi*Xi+ |
|-------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------|------|------|-------|-------|------|------|------|------|-----------------|-------------------|----------------------|--------|
| Interpretation          | Class             | 1                                                                                                                                                                                                           | 2     | 3     | 4    | 5    | 6     | 7     | 8    | 9    | 10   | 11   |                 |                   |                      |        |
|                         | 1                 | 1                                                                                                                                                                                                           |       |       |      |      |       |       |      |      |      |      | 1               | 100               | 0                    | 1      |
|                         | 2                 |                                                                                                                                                                                                             | 18    |       |      | 2    |       |       |      |      |      |      | 20              | 90.0              | 10.0                 | 480    |
|                         | 3                 |                                                                                                                                                                                                             | 2     | 6     |      |      |       |       |      |      |      |      | 8               | 75.0              | 25.0                 | 80     |
|                         | 4                 |                                                                                                                                                                                                             |       | 3     | 73   |      |       | 1     |      |      |      |      | 77              | 94.8              | 5.2                  | 5698   |
|                         | 5                 |                                                                                                                                                                                                             | 3     |       |      | 59   |       |       |      |      |      |      | 62              | 95.2              | 4.8                  | 3782   |
|                         | 6                 |                                                                                                                                                                                                             |       |       |      |      | 4     |       |      |      |      |      | 4               | 100               | 0.0                  | 16     |
|                         | 7                 |                                                                                                                                                                                                             |       | 1     |      |      |       | 9     | 2    |      |      |      | 12              | 75.0              | 25.0                 | 132    |
|                         | 8                 |                                                                                                                                                                                                             |       |       |      |      |       | 1     | 35   |      |      |      | 36              | 97.2              | 2.8                  | 1332   |
|                         | 9                 |                                                                                                                                                                                                             |       |       |      |      |       |       |      | 4    |      |      | 4               | 100               | 0                    | 16     |
|                         | 10                |                                                                                                                                                                                                             | 1     |       |      |      |       |       | 1    |      |      | 3    | 5               | 60.0              | 40.0                 | 15     |
| 11                      |                   |                                                                                                                                                                                                             |       |       |      |      |       |       |      |      | 4    | 4    | 100             | 0                 | 16                   |        |
| Column Totals (Xi+)     |                   | 1                                                                                                                                                                                                           | 24    | 10    | 74   | 61   | 4     | 11    | 37   | 4    | 3    | 4    | 216 (Xii)       | 233 (N)           | 11568 (Total Xi*Xi+) |        |
| Producer Accuracy (%)   |                   | 100                                                                                                                                                                                                         | 75.0  | 60.0  | 98.6 | 96.7 | 100.0 | 81.8  | 94.6 | 100  | 100  | 100  |                 |                   |                      |        |
| Omission error (%)      |                   | 0.0%                                                                                                                                                                                                        | 25.0% | 40.0% | 1.4% | 3.3% | 0.0%  | 18.2% | 5.4% | 0.0% | 0.0% | 0.0% |                 |                   |                      |        |
| Overall Accuracy: 92.7% |                   | 1: YIA Airport; 2: Industry and Tourism; 3: Bare land; 4: Plantations; 5: Rural Settlement; 6: Urban Settlement; 7: Dryland Farming; 8: Rice Field; 9: Coastal Area; 10: Fishpond; 11: Water Bodies / River |       |       |      |      |       |       |      |      |      |      |                 |                   |                      |        |
| Koefisien Kappa: 0.907  |                   |                                                                                                                                                                                                             |       |       |      |      |       |       |      |      |      |      |                 |                   |                      |        |

Source: Analysis Results, 2024

The accuracy assessment of land cover interpretation in the coastal area of Kulon Progo Regency in 2024 is presented in Table 3. Referring to the table, the land cover interpretation using Sentinel-2 imagery achieved an overall accuracy of 92.7% and a Kappa coefficient of 0.907. The Kappa value, which approaches 1, indicates a high level of confidence in the classification results. This accuracy level is considered high, suggesting that the interpretation is reliable (>85%) and can serve as a credible reference for further research. The high accuracy demonstrates that the interpreted land cover closely represents the actual land cover conditions on the ground. Any discrepancies between the interpreted results and field observations were updated to ensure the data accurately reflect real conditions

### Distribution of Land Cover Change

The most significant factor in urban development is the availability of infrastructure which support people movement, such as network transportation (Aburas, 2017; Zhou, 2020). Especially the area with accessibility near the Southern Cross Road Network (JJLS) (Pratiwi and Rahardjo, 2018). Wang, et al, (2010) and Muhammad (2022), stated that newly developed transportation infrastructure is the driving forces that could trigger spatial structure changes. Furthermore, transport infrastructure is a crucial aspect that engages the increase economic development and improve citizen well-being (Ghent, 2018). It is proved by Cao (2020) and Chadchan (2012) that main road is a significant aspect that affect urban development. In addition, the existence of main road construction can affect on reducing agricultural land due to the increase of land conversion if

the area is located near roads and residential developments (Tang et al, 2023; Girsang, 2025; Buğday, 2019).Paramita (2011) stated that the increase in development of a region is generally along road corridors and regional centers. The phenomenon of regional development can occur by following transportation routes (Yunus, 2000). This theory can be proven by looking at changes in the appearance of land use that occurred in the period 2016 to 2024. Changes in land use in the period 2016, 2020 and 2024 are listed in table 3.

**Table 3.** Changes in land use over the years 2016, 2020, and 2024

| Land Cover<br>Classifications | Area (ha)        |                  |                 |                  |                  |                 |
|-------------------------------|------------------|------------------|-----------------|------------------|------------------|-----------------|
|                               | 2016             | 2020             | Δ 2016-<br>2020 | 2020             | 2024             | Δ 2020-<br>2024 |
| <b>A Built-Up Area</b>        | <b>1.312</b>     | <b>2.424,3</b>   | <b>1.112,3</b>  | <b>2.424,3</b>   | <b>3.038</b>     | <b>613,7</b>    |
| YIA Airport                   | -                | 580,96           | 580,96          | 580,96           | 580,96           | 0               |
| Industry, trade and tourism   | 98,69            | 137,02           | 38,33           | 137,02           | 197,12           | 60.1            |
| Rural Settlement              | 1.108,92         | 1.544,25         | 435,33          | 1.544,25         | 2.067,06         | 522.81          |
| Urban Settlement              | 104,39           | 162,07           | 57,68           | 162,07           | 192,86           | 30.79           |
| <b>B Non-Built-Up Area</b>    | <b>13.083,19</b> | <b>11.970,89</b> | <b>-1.112,3</b> | <b>11.970,89</b> | <b>11.357,19</b> | <b>-613,7</b>   |
| Bare land                     | 13,17            | 13,99            | 0,82            | 13,99            | 17,62            | 3.63            |
| Plantation                    | 5.284,13         | 4.693,89         | -590,24         | 4.693,89         | 4.148,18         | -545.71         |
| Dry land farming              | 2.116,24         | 1.740,87         | -375,37         | 1.740,87         | 1.706,64         | -34.23          |
| Rice field farming            | 4.921,85         | 4.805,07         | -116,78         | 4.805,07         | 4.770,39         | -34.68          |
| Beach border                  | 206,24           | 259,83           | 53,59           | 259,83           | 263,75           | 3.92            |
| Fishpond/ pond                | 300,75           | 216,43           | -84,32          | 216,43           | 209,8            | -6.63           |
| Body of water                 | 240,81           | 240,81           | 0               | 240,81           | 240,81           | 0               |
| <b>Total Area</b>             | <b>14.395,19</b> |                  | <b>0</b>        | <b>14.395,19</b> |                  | <b>0</b>        |

Based on the table above, the land use conditions in 2016 to 2024 have experienced quite significant changes. This is due to the construction of Yogyakarta International Airport (YIA) and the South Cross Road (JJLS) as one of the national strategic projects. YIA Airport has an area of 580,96 ha which contributes to changes in built-up area and non-built-up area.

The table shows that land use in 2016 was dominated by non-built-up area in the form of plantations, rice fields, and dry land farming with an area of 12.322 ha or 85,6% of the total area of the study area. Meanwhile, the total area of built-up area cover in the form of rural settlements, urban settlements, industry, trade, and tourism was only 1.312 ha or 9,1% of the total area of the study area.

Meanwhile, the total change in non-built-up area cover to built-up area in 2020 to 2024 was 613,7 ha.

Based on this value, there was an increase in built-up area of 82,36 ha or 16% when compared to the growth in the period from 2016 to 2020. The significant change in built-up land in the period from 2020 to 2024 was caused by several driving factors of change that gave rise to characteristics of urban activities in the community environment, such as the development of JJLS and the construction of YIA Airport (Pamungkas, 2023).

**Analysis of Built-up Area Development 2016-2024**

Based on the results of the RCI calculation in 2016 to 2020, the lowest RCI value was 0.2917 and the highest value was 3.156. Meanwhile, the RCI value for 2020 to 2024 had the lowest value of 0,3862 and the highest was 2,1791. Based on the RCI value, it is divided into 3 classes, low, medium, and high in order to represent the intensity of change in each village.

**Table 4.** RCI Values and Classification of Change Intensity in Each Village in 2016-2020

| Subdistrict | No Village | Village     | RCI Parameters |        |        |          | RCI<br>( $\frac{RDK}{RTK}$ ) | Intensity of<br>Change |
|-------------|------------|-------------|----------------|--------|--------|----------|------------------------------|------------------------|
|             |            |             | ADK            | AD     | RDK    | RTK      |                              |                        |
| Galur       | 1          | Karangsewu  | 30,56          | 794,91 | 0,0384 | 544,67   | 0,7943                       | Low                    |
|             | 2          | Banaran     | 21,00          | 598,91 | 0,0351 | 11970,89 | 0,7245                       | Low                    |
|             | 3          | Tirtorahayu | 20,21          | 471,84 | 0,0428 | = 0,0455 | 0,8850                       | Low                    |
|             | 4          | Nomporejo   | 8,49           | 151,20 | 0,0562 |          | 1,1602                       | Moderate               |
|             | 5          | Pandowan    | 7,85           | 109,01 | 0,0720 |          | 1,4879                       | Moderate               |
|             | 6          | Kranggan    | 11,00          | 179,12 | 0,0614 |          | 1,2689                       | Moderate               |
|             | 7          | Brosot      | 17,07          | 216,54 | 0,0788 |          | 1,6288                       | Moderate               |
| Panjatan    | 8          | Bugel       | 15,71          | 598,71 | 0,0262 |          | 0,5422                       | Low                    |
|             | 9          | Gorongan    | 12,89          | 561,67 | 0,0229 |          | 0,4742                       | Low                    |
|             | 10         | Krembangan  | 12,70          | 451,05 | 0,0282 |          | 0,5818                       | Low                    |
|             | 11         | Cerme       | 13,56          | 385,91 | 0,0351 |          | 0,7260                       | Low                    |
|             | 12         | Gotakan     | 11,92          | 293,81 | 0,0406 |          | 0,8383                       | Low                    |
|             | 13         | Panjatan    | 5,37           | 105,25 | 0,0510 |          | 1,0542                       | Low                    |
|             | 14         | Kanoman     | 3,43           | 242,93 | 0,0141 |          | 0,2917                       | Low                    |
|             | 15         | Depok       | 8,26           | 199,95 | 0,0413 |          | 0,8535                       | Low                    |
|             | 16         | Bojong      | 8,23           | 342,56 | 0,0240 |          | 0,4964                       | Low                    |
|             | 17         | Pleret      | 15,86          | 523,29 | 0,0303 |          | 0,6262                       | Low                    |
|             | 18         | Tayuban     | 8,62           | 194,21 | 0,0444 |          | 0,9171                       | Low                    |
| Temon       | 19         | Jangkaran   | 12,08          | 110,52 | 0,1093 |          | 2,2584                       | Hight                  |
|             | 20         | Sindutan    | 13,61          | 174,93 | 0,0778 |          | 1,6075                       | Moderate               |
|             | 21         | Glagah      | 31,22          | 237,11 | 0,1317 |          | 2,7205                       | Hight                  |
|             | 22         | Karangwuluh | 6,72           | 138,86 | 0,0484 |          | 0,9999                       | Low                    |
|             | 23         | Janten      | 8,40           | 123,07 | 0,0683 |          | 1,4102                       | Moderate               |
|             | 24         | Palihan     | 19,42          | 127,14 | 0,1527 |          | 3,1560                       | Hight                  |
|             | 25         | Kebonrejo   | 9,05           | 102,71 | 0,0881 |          | 1,8205                       | Moderate               |
|             | 26         | Temonkulon  | 10,17          | 142,17 | 0,0715 |          | 1,4780                       | Moderate               |
|             | 27         | Plumbon     | 9,77           | 271,62 | 0,0360 |          | 0,7432                       | Low                    |
|             | 28         | Demen       | 6,03           | 69,64  | 0,0866 |          | 1,7891                       | Moderate               |
|             | 29         | Kedundang   | 9,83           | 131,65 | 0,0747 |          | 1,5428                       | Moderate               |
|             | 30         | Kulur       | 5,40           | 204,47 | 0,0264 |          | 0,5457                       | Low                    |
|             | 31         | Temonwetan  | 7,10           | 154,53 | 0,0459 |          | 0,9493                       | Low                    |
|             | 32         | Kalidengen  | 6,72           | 132,00 | 0,0509 |          | 1,0519                       | Low                    |
|             | 33         | Kaligintung | 5,12           | 291,99 | 0,0175 |          | 0,3623                       | Low                    |
| Wates       | 34         | Karangwuni  | 13,52          | 547,63 | 0,0247 |          | 0,5101                       | Low                    |
|             | 35         | Sogan       | 10,16          | 216,08 | 0,0470 |          | 0,9715                       | Low                    |
|             | 36         | Wates       | 25,76          | 237,32 | 0,1085 |          | 2,2427                       | Hight                  |
|             | 37         | Giripeni    | 35,05          | 406,50 | 0,0862 |          | 1,7815                       | Moderate               |
|             | 38         | Kuwaru      | 12,24          | 218,51 | 0,0560 |          | 1,1574                       | Low                    |
|             | 39         | Triharjo    | 25,86          | 343,15 | 0,0754 |          | 1,5571                       | Moderate               |
|             | 40         | Ngestiharjo | 8,91           | 212,64 | 0,0419 |          | 0,8658                       | Low                    |
|             | 41         | Bendungan   | 19,80          | 238,71 | 0,0829 |          | 1,7138                       | Moderate               |

Source: Analysis Results, 2024

**Table 5.** RCI Values and Classification of Change Intensity in Each Village in 2020-2024

| Subdistrict | No Village | Village     | RCI Parameters |        |        |                      | RCI<br>( $\frac{RDK}{RTK}$ ) | Intensity<br>(2020-2024) |
|-------------|------------|-------------|----------------|--------|--------|----------------------|------------------------------|--------------------------|
|             |            |             | ADK            | AD     | RDK    | RTK                  |                              |                          |
| Galur       | 1          | Karangsewu  | 36,22          | 758,69 | 0,0477 | 609,74               | 0,8333                       | Moderate                 |
|             | 2          | Banaran     | 18,30          | 580,61 | 0,0315 | 10642,83<br>= 0,0573 | 0,5501                       | Low                      |
|             | 3          | Tirtorahayu | 17,03          | 454,81 | 0,0374 |                      | 0,6536                       | Low                      |
|             | 4          | Nomporejo   | 6,95           | 144,25 | 0,0482 |                      | 0,8410                       | Moderate                 |
|             | 5          | Pandowan    | 6,47           | 102,54 | 0,0631 |                      | 1,1013                       | Moderate                 |
|             | 6          | Kranggan    | 9,45           | 169,67 | 0,0557 |                      | 0,9722                       | Moderate                 |
|             | 7          | Brosot      | 23,97          | 192,57 | 0,1245 |                      | 2,1727                       | Hight                    |
| Panjatan    | 8          | Bugel       | 21,31          | 577,40 | 0,0369 |                      | 0,6442                       | Low                      |
|             | 9          | Gorongan    | 18,60          | 543,07 | 0,0342 |                      | 0,5978                       | Low                      |
|             | 10         | Krembangan  | 26,16          | 424,89 | 0,0616 |                      | 1,0747                       | Moderate                 |
|             | 11         | Cerme       | 32,48          | 353,43 | 0,0919 |                      | 1,6041                       | Moderate                 |
|             | 12         | Gotakan     | 21,18          | 272,63 | 0,0777 |                      | 1,3560                       | Moderate                 |
|             | 13         | Panjatan    | 7,48           | 97,77  | 0,0765 |                      | 1,3354                       | Moderate                 |
|             | 14         | Kanoman     | 8,66           | 234,27 | 0,0370 |                      | 0,6452                       | Low                      |
|             | 15         | Depok       | 11,72          | 188,23 | 0,0623 |                      | 1,0868                       | Moderate                 |
|             | 16         | Bojong      | 14,21          | 328,35 | 0,0433 |                      | 0,7554                       | Low                      |
|             | 17         | Pleret      | 22,06          | 501,23 | 0,0440 |                      | 0,7682                       | Low                      |
|             | 18         | Tayuban     | 11,73          | 182,48 | 0,0643 |                      | 1,1220                       | Moderate                 |
| Temon       | 19         | Jangkaran   | 9,58           | 100,94 | 0,0949 |                      | 1,6566                       | Hight                    |
|             | 20         | Sindutan    | 8,33           | 166,60 | 0,0500 |                      | 0,8727                       | Moderate                 |
|             | 21         | Glagah      | 14,64          | 222,47 | 0,0658 |                      | 1,1486                       | Moderate                 |
|             | 22         | Karangwuluh | 3,49           | 135,37 | 0,0258 |                      | 0,4500                       | Low                      |
|             | 23         | Janten      | 5,52           | 117,55 | 0,0470 |                      | 0,8197                       | Moderate                 |
|             | 24         | Palihan     | 13,70          | 113,44 | 0,1208 |                      | 2,1080                       | Hight                    |
|             | 25         | Kebonrejo   | 8,32           | 94,39  | 0,0881 |                      | 1,5385                       | Moderate                 |
|             | 26         | Temon Kulon | 11,74          | 130,43 | 0,0900 |                      | 1,5711                       | Moderate                 |
|             | 27         | Plumbon     | 7,51           | 264,11 | 0,0284 |                      | 0,4963                       | Low                      |
|             | 28         | Demen       | 3,18           | 66,46  | 0,0478 |                      | 0,8352                       | Moderate                 |
|             | 29         | Kedundang   | 8,40           | 123,25 | 0,0682 |                      | 1,1896                       | Moderate                 |
|             | 30         | Kulur       | 6,44           | 198,03 | 0,0325 |                      | 0,5676                       | Low                      |
|             | 31         | Temon Wetan | 6,45           | 148,08 | 0,0436 |                      | 0,7603                       | Low                      |
|             | 32         | Kalidengen  | 7,58           | 124,42 | 0,0609 |                      | 1,0634                       | Moderate                 |
|             | 33         | Kaligintung | 6,32           | 285,67 | 0,0221 |                      | 0,3862                       | Low                      |
| Wates       | 34         | Karangwuni  | 20,06          | 526,32 | 0,0381 |                      | 0,6653                       | Low                      |
|             | 35         | Sogan       | 9,07           | 207,01 | 0,0438 |                      | 0,7648                       | Low                      |
|             | 36         | Wates       | 26,34          | 210,98 | 0,1248 |                      | 2,1791                       | Hight                    |
|             | 37         | Giripeni    | 41,74          | 364,76 | 0,1144 |                      | 1,9974                       | Hight                    |
|             | 38         | Kuwaru      | 12,19          | 206,32 | 0,0591 |                      | 1,0313                       | Moderate                 |
|             | 39         | Triharjo    | 30,74          | 312,41 | 0,0984 |                      | 1,7175                       | Hight                    |
|             | 40         | Ngestiharjo | 10,36          | 202,28 | 0,0512 |                      | 0,8940                       | Moderate                 |
|             | 41         | Bendungan   | 24,06          | 214,65 | 0,1121 |                      | 1,9565                       | Hight                    |

Based on the RCI value classification in each village, the intensity of change in the 2016-2020 period, there are four villages that have a high intensity change classification, specifically Wates Village, Palihan Village, Glagah Village, and Jangkaru Village. Meanwhile, there are thirteen villages with a moderate intensity change classification, and twenty-four villages are included in the villages with a low intensity change classification. Furthermore, all villages in Panjatan District have a low intensity of land cover change classification.

The intensity of land cover change in the 2020-2024 is distributed fairly. There is a significant decrease in the number of villages with a low change intensity classification from the previous period of twenty-four to fourteen villages. Meanwhile, there is an increase in the number of villages with a medium change intensity classification from the previous thirteen to twenty and for the high change intensity classification it has increased from four to seven villages. This shows an increase in the quality and equity of development in the development of built-up area in the 2020 to 2024 period. The high intensity of land cover change indicated by the RDK which is the ratio between area a new-built land (ADK) with remaining area of agricultural land (AD).

The RTK value in 2016-2020 was 0,0455, while the RTK value in 2020-2024 was 0,0573, which shows that the ratio or intensity of land changes in the study area, namely part of the coastal area of Kulon Progo Regency, has experienced a significant increase.

Analysis to determine the development of built-up area is presented spatially using a land change intensity map, the unit of analysis used is village administration. Based on the built-up area change intensity map for 2016-2020 and 2020-2024 (Figure 3 and Figure 4), it can be seen that villages with low change intensity values tend to be in the southern part or are closely associated with the southern coast which is dominated by rice field agricultural land cover and dry land agriculture such as in Banaran Village, Tirtorahayu Village, Bugel Village, Gorongan Village, Bojong Village, Sogan Village, Plumbon Village, and Karangwuni Village. Meanwhile, Karangwuluh Village, Kaligintung Village, Kulur Village, and Temon Wetan Village have low change intensity because they are located in areas with steep topography with undulating relief characteristics because they are included in the Menoreh Hills area, thus inhibiting the growth rate of built-up area.

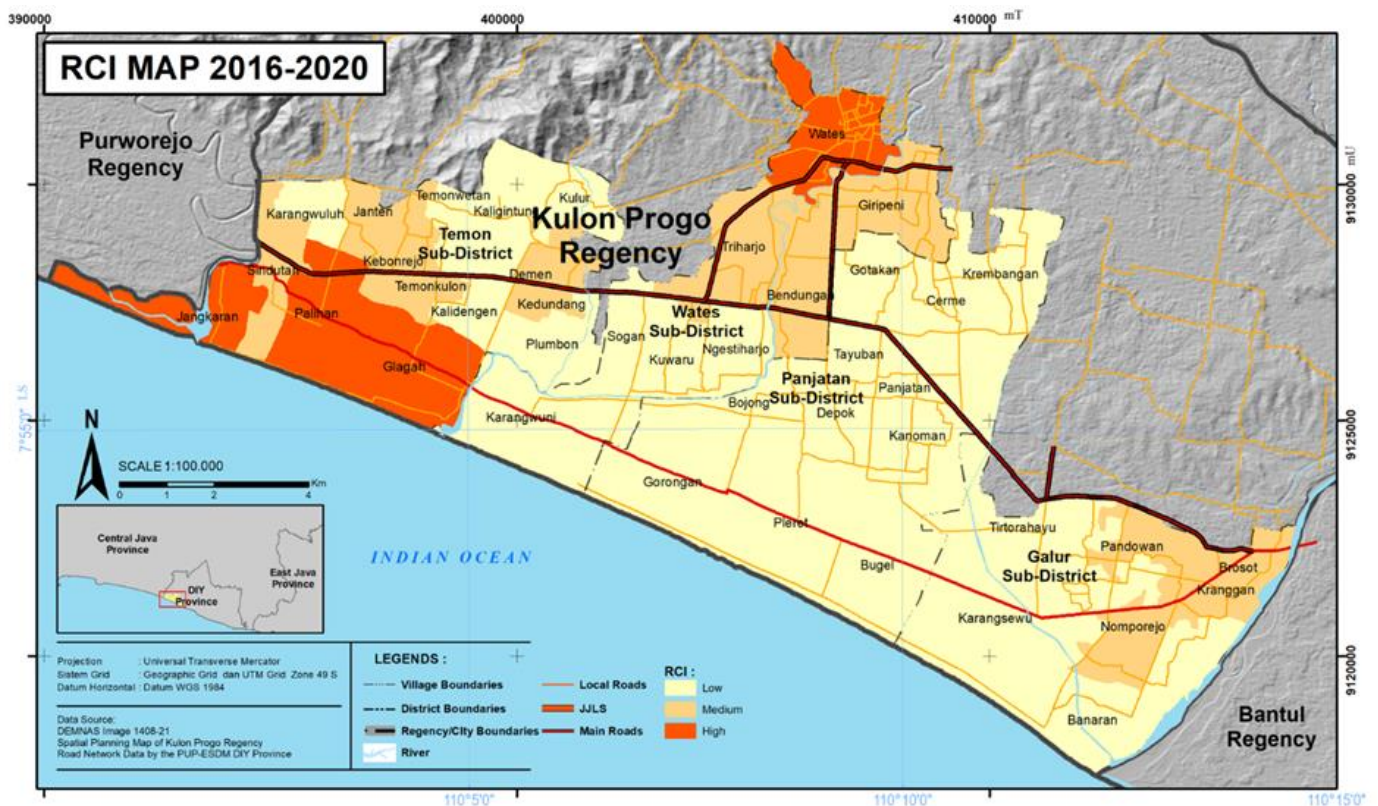
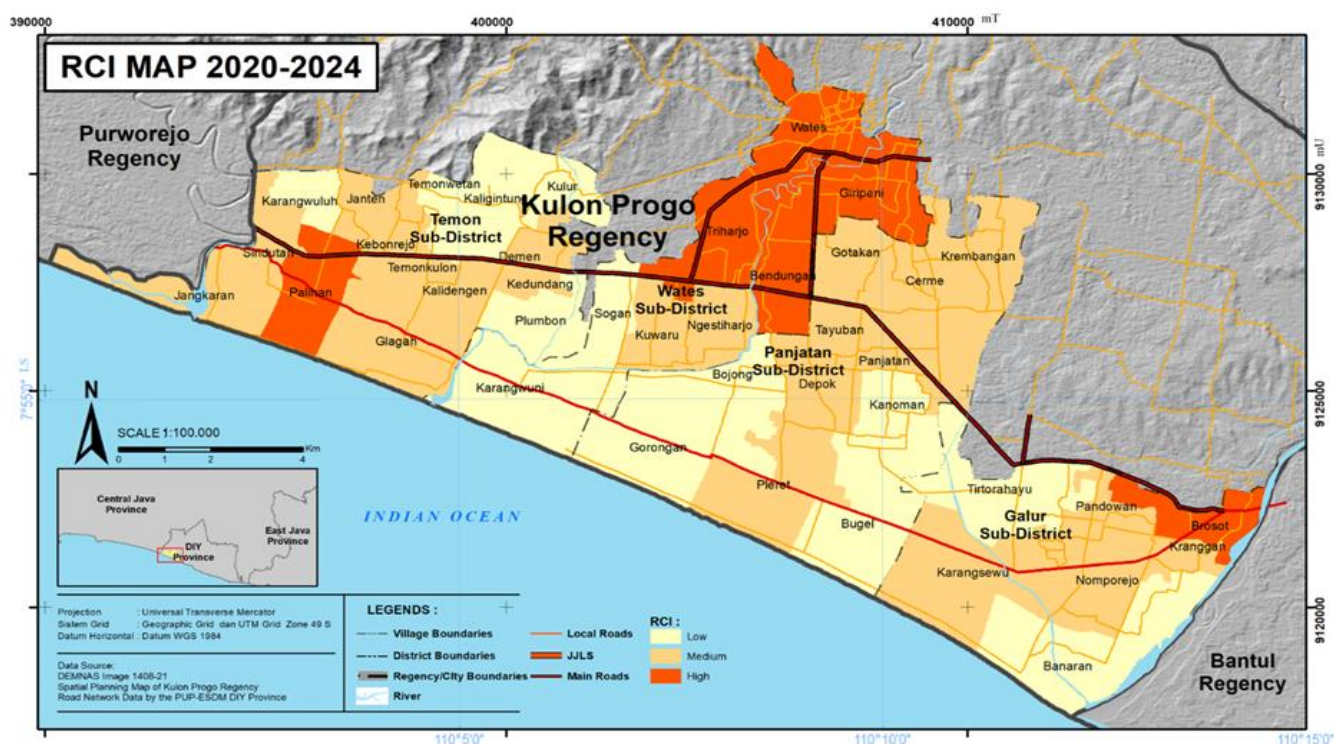


Figure 3. Map of Built-up Area Change Intensity Using the RCI Method for 2016-2020



**Figure 4.** Built-up Area Change Intensity Map Using the RCI Method for 2020-2024

#### Impact of JJLS on Built-up Area Development

To find out how much influence JJLS has on the development of built-up area in the surrounding area using statistical analysis of linear regression test whose results can be interpreted through the significance value (Sig.), correlation coefficient (R), and determination coefficient (R squared). Linear regression analysis uses buffer technique to find out how much growth of built-up area is located on the right and left of JJLS which will then be used as a variable. The buffer technique is carried out

in both time periods, namely the period of built-up area development from 2016 to 2020 and the period of built-up area development from 2020 to 2024. The magnitude of the influence of JJLS on the growth of built-up area in some coastal areas of Kulon Progo Regency is stated in table 6 and the graphs in figures 5 and 6 which show the correlation between the distance of the land buffer to JJLS and the magnitude of the area of built-up area growth that occurs.

**Table 6.** Statistical calculation of the influence of JJLS on built-up area growth

##### A. Linear Regression 2016-2020

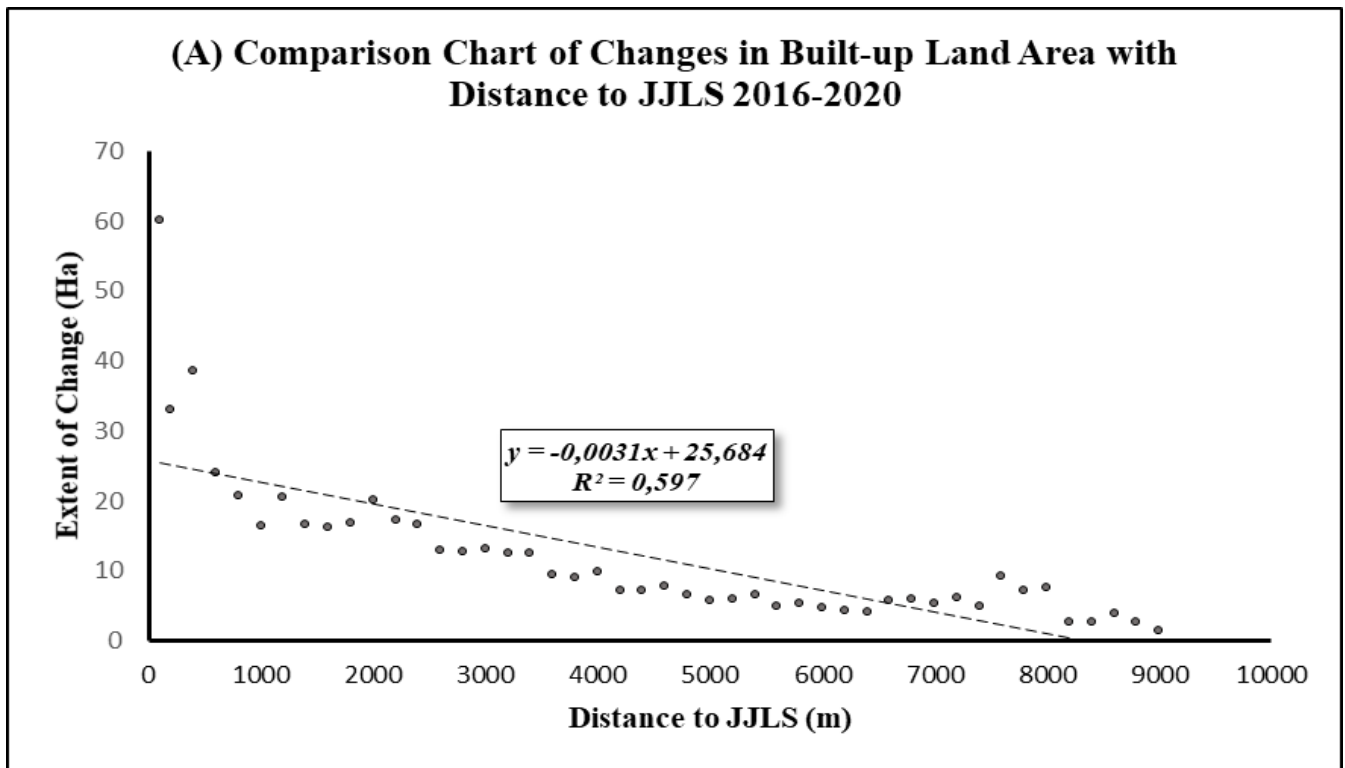
| Model | R                 | R Square | Adjusted R Square | Std. Error of the Estimate | R Square Change | F Change | Sig   |
|-------|-------------------|----------|-------------------|----------------------------|-----------------|----------|-------|
|       | .773 <sup>a</sup> | .597     | .588              | 6.84807                    | .597            | 65.207   | <.001 |

a. Predictors: (Constant), Distance

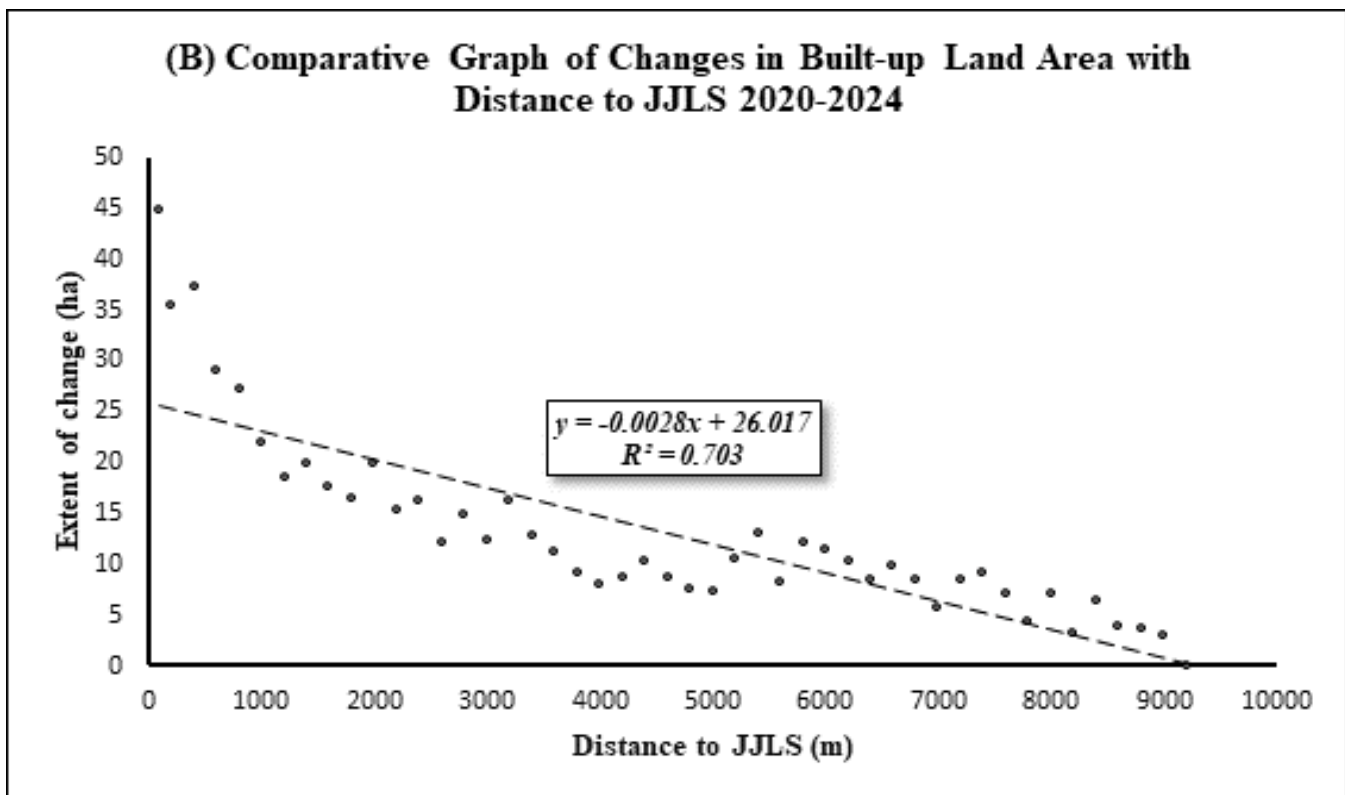
##### B. Linear Regression 2020-2024

| Model | R                 | R Square | Adjusted R Square | Std. Error of the Estimate | R Square Change | F Change | Sig   |
|-------|-------------------|----------|-------------------|----------------------------|-----------------|----------|-------|
|       | .838 <sup>a</sup> | .703     | .696              | 5.07259                    | .703            | 106.334  | <.001 |

a. Predictors: (Constant), Distance



**Figure 6.** Comparison graph of built-up area with JJLS Buffer 2016-2020



**Figure 7.** Comparison graph of built-up area with JJLS Buffer 2016-2020

Based on the results of the linear regression test, the significance value (Sig.) was obtained in two year periods which showed a value of  $<0,001$  or less than 0,05 so that it can be concluded that the regression model is statistically significant. This means that the distance variable significantly affects changes in land cover area. Then the value (R) or correlation coefficient in the results of the regression test for 2016-2020 and the period 2020-2024 showed values of 0,773 and 0,838, respectively. This states that there is a strong influence between the JJLS variable and the growth of built-up area in the study area. Furthermore, the coefficient of determination (R Square) value is 0,597 in the period 2016-2020 and 0,703 in the period 2020-2024. If the coefficient value is closer to 1, the relationship between JJLS and land cover changes is very close (Alipbeki, 2024). Meanwhile, the coefficient of determination (R squared) value explains how large a percentage the independent variable contributes to explaining or even predicting the value of the dependent variable (Santoso, 2018). Based on the determination coefficient value obtained, JJLS as an independent variable has an influence on changes in built-up area area of 59% in the 2016-2020 period and its influence increases to 70% in the 2020 to 2024 period.

## CONCLUSION

The development of functional infrastructure in the form of JJLS in Kulon Progo Regency has a positive impact on increasing the economy of the community and region. Although it has a good impact on the economy, the dynamics of rapid changes in built-up area can have a negative impact on the environment due to the high conversion of land functions. Land use from 2016 to 2024 has changed quite significantly. Land use in 2016 was dominated by non-built-up area in the form of plantations, rice fields, and dry land agriculture which had an area of 12.322 ha or 85.6% of the total area of the study area. Meanwhile, the total area of built-up area cover in the form of village settlements, urban settlements, industry, trade, and tourism was only 1.312 ha or 9,1% of the total area of the study area. For 2024, there was a significant increase in the use of built-up area in the form of industrial trade and residential areas, and there was a significant decrease in the use of non-built-up area in the form of plantations, urban land agriculture, rice fields and ponds.

Based on the RCI value, it is divided into 3 classes, low, medium, and high, to represent the intensity

of change in each village. Based on the results of the RCI calculation in 2016 to 2020, the lowest RCI value was 0,2917 and the highest value was 3,156. While the RCI value for 2020 to 2024 has the lowest value of 0.3862 and the highest is 2,1791. Based on the RCI value, it is divided into 3 classes, low, medium, and high, to represent the intensity of change in each village. The conclusion from the results of the statistical analysis shows that there is a significant influence between the JJLS variable on the growth of built-up area in this study area.

This study has several limitations. First, the analysis of land use changes resulting from the development of the Southern Cross Road Network (JJLS) in Kulon Progo was limited to a general classification of land use, specifically distinguishing between built-up and non-built-up areas. This approach does not capture more detailed land categories, such as residential areas, public facilities, agricultural land, or protected zones. Second, limited availability of field validation data and spatial accuracy may affect the reliability of the land use classification results. Future studies are encouraged to apply a more detailed and specific land use classification to better capture the diverse impacts of JJLS development on various land types. Additionally, integrating socio-economic data and adopting participatory approaches involving local communities can provide deeper insights into the dynamics of land use change in affected areas.

**Conflict of Interest** The author declares that he has no conflict of interest relevant to this research.

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## REFERENCES

- Aburas, M. M., Ho, Y. M., Ramli, M. F., & Ash'aari, Z. H. (2017). Improving the capability of an integrated CA-Markov model to simulate spatio-temporal urban growth trends using an Analytical Hierarchy Process and Frequency Ratio. *International Journal of Applied Earth Observation and Geoinformation*, 59, 65-78. <https://doi.org/10.1016/j.jag.2017.03.006>
- Ahasan, R., & Güneralp, B. (2022). Transportation in urban land change models: a systematic review and future directions. *Journal of Land Use Science*, 17(1), 351-367. <https://doi.org/10.1080/1747423X.2022.2086639>

- Arfa, A., & Minaei, M. (2024). Utilizing multitemporal indices and spectral bands of Sentinel-2 to enhance land use and land cover classification with random forest and support vector machine. *Advances in Space Research*, 74(11), 5580-5590. <https://doi.org/10.1016/j.asr.2024.08.062>
- Badan Standarisasi Nasional. (2014). Klasifikasi penutup lahan – Bagian 1: Skala kecil dan menengah. Diakses 22 Maret 2023, dari <https://www.bsn.go.id>
- Bintoro, A. Y. (2008). Pengaruh ruas jalan arteri Soekarno - Hatta terhadap fisik kawasan di sekitarnya (Tesis Magister, Universitas Diponegoro). Universitas Diponegoro.
- Buğday, E., & Buğday, S. E. (2019). Modeling and simulating land use/cover change using artificial neural network from remotely sensing data. *Cerne*, 25, 246-254. <https://doi.org/10.1590/01047760201925022634>
- Cao, Y., Zhang, X., Fu, Y., Lu, Z., & Shen, X. (2020). Urban spatial growth modeling using logistic regression and cellular automata: A case study of Hangzhou. *Ecological indicators*, 113, 106200. <https://doi.org/10.1016/j.ecolind.2020.106200>
- Chadchan, J., & Shankar, R. (2012). An analysis of urban growth trends in the post-economic reforms period in India. *International Journal of Sustainable Built Environment*, 1(1), 36-49. <https://doi.org/10.1016/j.ijsbe.2012.05.001>
- Dehghani, A., Soltani, A., & Nateghi, K. (2025). Balancing Urban Growth and Environmental Change: Land Use Patterns in Tehran and Sydney. *Environmental and Sustainability Indicators*, 100691. <https://doi.org/10.1016/j.indic.2025.100691>
- Dinda, R., Mariati, H., & Fitriawan, D. (2022). Analisis Proyeksi Penduduk dan Alokasi Kebutuhan Lahan Permukiman Di Kota Padang 2020-2030. *Jurnal Azimut*, 4(1), 19-27. <https://doi.org/10.31317/jaz.v4i1.790>
- Edy, H., & Tantin, P. (2021). Dampak pembangunan Jalur Jalan Lintas Selatan (JLS) terhadap perubahan penggunaan lahan. *Jurnal Media Komunikasi Dunia Ilmu Sipil (MoDuluS)*, 3(1), 7-11. <https://doi.org/10.32585/modulus.v3i1.1770>
- European Space Agency (ESA). (2015). Sentinel-2 user handbook (2nd ed.). ESA Standard Document. [https://sentinel.esa.int/documents/247904/685211/Sentinel-2\\_User\\_Handbook](https://sentinel.esa.int/documents/247904/685211/Sentinel-2_User_Handbook)
- Ghent, C. (2018). Mitigating the effects of transport infrastructure development on ecosystems. *Consilience*, (19), 58-68. <https://www.jstor.org/stable/26427712>
- Girsang, S. S. B., Banurea, D. M., Lestari, P., Nambela, J. B., Verawaty, I., Barus, J., ... & Purba, T. (2025). Dynamics prediction of land use changes using cellular automata and artificial neural network modeling. *Global Journal of Environmental Science and Management*, 11(2), 427-442. <https://doi.org/10.22034/gjesm.2025.02.04>
- Giyarsih, S. R. (2010). Pola Spasial Transformasi Wilayah di Koridor Yogyakarta-Surakarta. *Forum Geografi*, 24(1), 28. <http://dx.doi.org/10.23917/forgeo.v24i1.5013>
- Hakim Sinaga, S., Suprayogi, A., & Haniah. (2018). Analisis Ketersediaan Ruang Terbuka Hijau Dengan Metode Normalized Difference Vegetation Index Dan Soil Adjusted Vegetation Index Menggunakan Citra Satelit Sentinel 2A (Studi Kasus: Kabupaten Demak). *Jurnal Geodesi Undip Januari*, 7(1). <https://doi.org/10.14710/jgundip.2017.19329>
- Handayani, H. H., Murayama, Y., Ranagalage, M., Liu, F., & Dissanayake, D. (2018). Geospatial Analysis of Horizontal and Vertical Urban Expansion Using Multi-Spatial Resolution Data: A Case Study of Surabaya, Indonesia. *Remote Sensing*, 10(10), 1599. <https://doi.org/10.3390/rs10101599>
- Indriana, I., & Nando, J. (2024). Drone Multispektral Dalam Pemetaan Tutupan Lahan Kajai, Pasaman Barat, Sumatera Barat, Indonesia. *Jurnal Penelitian Geografi (JPG)*, 12(1), 73-79. <https://doi.org/10.23960/jpg.v12i1.29638>
- Lillesand, T. M., Kiefer, R. W., & Chipman, J. W. (2015). *Remote Sensing and Image Interpretation* (7th ed.). New York: John Wiley & Sons, Inc.
- Muhammad, R., Zhang, W., Abbas, Z., Guo, F., & Gwiazdzinski, L. (2022). Spatiotemporal change analysis and prediction of future land use and land cover changes using QGIS MOLUSCE plugin and remote sensing big data: A case study of Linyi, China. *Land*, 11(3), 419. <https://doi.org/10.3390/land11030419>
- Pamungkas, B. (2023). Pemanfaatan geoinformatik untuk analisis perubahan penggunaan lahan dan risiko

- tsunami di sebagian pesisir Kabupaten Kebumen (Tesis Magister, Universitas Gadjah Mada). Universitas Gadjah Mada.
- Paramitha, B. A. P. (2011). Model cellular automata untuk prediksi perkembangan wilayah menggunakan citra penginderaan jauh resolusi menengah (Studi kasus wilayah Kedungsepur) (Tesis Magister, Fakultas Geografi, Universitas Gadjah Mada). Universitas Gadjah Mada.
- Pemerintah Daerah Daerah Istimewa Yogyakarta. (2016). Surat Keputusan Gubernur DIY Nomor 118/KEP/2016 tentang Penetapan Ruas Jalan Provinsi. Yogyakarta: Pemerintah Provinsi DIY.
- Pemerintah Indonesia. (2021). Peraturan Pemerintah Republik Indonesia Nomor 21 Tahun 2021 tentang Penyelenggaraan Penataan Ruang.
- Phiri, D., Simwanda, M., Salekin, S., Nyirenda, V. R., Murayama, Y., & Ranagalage, M. (2020). Sentinel-2 Data for Land Cover/Use Mapping: A Review. *Remote Sensing*, 12(14), 2291. <https://doi.org/10.3390/rs12142291>
- Pratiwi, S. E. (2018). Pemodelan spasial harga lahan dan perubahannya akibat pembangunan Bandara New Yogyakarta International Airport di sekitar area bandara (Skripsi Sarjana, Universitas Gadjah Mada). Universitas Gadjah Mada.
- Pratomoatmojo, N. A. (2014). Landusesim sebagai aplikasi pemodelan dan simulasi spasial perubahan penggunaan lahan berbasis Sistem Informasi Geografis dalam konteks perencanaan wilayah dan kota. *Seminar Nasional Cities*, 69–80. <http://dx.doi.org/10.12962%2Fj2716179X.v13i1.7064>
- Pravitasari, A. E., Rustiadi, E., Priatama, R. A., Murtadho, A., Kurnia, A. A., Mulya, S. P., Saizen, I., Widodo, C. E., & Wulandari, S. (2021). Spatiotemporal Distribution Patterns and Local Driving Factors of Regional Development in Java. *ISPRS International Journal of Geo-Information*, 10(12), 812. <https://doi.org/10.3390/ijgi10120812>
- Pusat Teknologi dan Data Penginderaan Jauh LAPAN. (2015). Pedoman pengolahan data satelit multispektral secara digital supervised untuk klasifikasi. Lembaga Penerbangan dan Antariksa Nasional (LAPAN).
- Putri, S. H. (2024). Analisis proyeksi kebutuhan dan daya dukung lahan permukiman terhadap RTRW Kabupaten Kulon Progo tahun 2012–2032 (Skripsi Sarjana, Fakultas Geografi, Universitas Gadjah Mada). Universitas Gadjah Mada.
- Ramadhan, A. H. (2019). Analisis digital citra Landsat untuk identifikasi perkembangan lahan terbangun akibat pengembangan Jalur Jalan Lintas Selatan Jawa di sebagian Provinsi Jawa Tengah dan Daerah Istimewa Yogyakarta (Skripsi Sarjana, Fakultas Geografi, Universitas Gadjah Mada). Universitas Gadjah Mada.
- Richards, J.A. (2022). Supervised Classification Techniques. In: *Remote Sensing Digital Image Analysis*. Springer, Cham. [https://doi.org/10.1007/978-3-030-82327-6\\_8](https://doi.org/10.1007/978-3-030-82327-6_8)
- Rwanga, S. S., & Ndambuki, J. M. (2017). Accuracy assessment of land use/land cover classification using remote sensing and GIS. *International Journal of Geosciences*, 8(04), 611. <https://doi.org/10.4236/ijg.2017.84033>
- Salim, W., & Faoziyah, U. (2022). The effect of transport infrastructure on land-use change: The case of toll road and high-speed railway development in West Java. *J. Reg. City Plan*, 33(1), 48–65. <https://doi.org/10.5614/jpwk.2022.33.1.3>
- Santoso, A. B. (2018). Tutorial & solusi pengolahan data regresi. Agung Budi Santoso.
- Saputra, D. M. A. (2023). Pemanfaatan Citra Landsat 8 untuk Pemetaan Perubahan Penggunaan Lahan di Daerah Terdampak Erupsi Gunungapi Semeru (4 Desember 2021). *Jurnal Penelitian Geografi (JPG)*, 11(1), 1–10. <http://dx.doi.org/10.23960/jpg.v11i1.1-10>
- Sarun, S., Vineetha, P., Kumar, R., & Jayalekshmi, V. (2018). Spatial Analysis of Land Use and Land Cover Changes Using Spectral Indices in the Tsunami Affected Areas in Kerala, India. *Journal of Geography, Environment and Earth Science International*, 15(4), 1–11. <https://doi.org/10.9734/jgeesi/2018/41927>
- Sudjana, L., Sodikin, S., & Astarika, R. (2024). Spatiotemporal Dynamics of Mangrove Cover Change in Tanjungpinang City, Riau Islands Province. *Jurnal Penelitian Geografi (JPG)*, 12(2), 167–184. <https://dx.doi.org/10.31028/jpg>
- Surya, B., Ahmad, D. N. A., Sakti, H. H., & Sahban, H. (2020). Land Use Change, Spatial Interaction, and

- Sustainable Development in the Metropolitan Urban Areas, South Sulawesi Province, Indonesia. *Land*, 9(3), 95. <https://doi.org/10.3390/land9030095>
- Susilo, B. (2016). Map analysis and spatial statistic: Assessment of spatial variability of agriculture land conversion in urban fringe area of Yogyakarta (Laporan penelitian, Fakultas Geografi, Universitas Gadjah Mada). Universitas Gadjah Mada.
- Tang, Z.; Wang, Y.; Fu, M.; Xue, J., (2023). The role of land use landscape patterns in the carbon emission reduction: Empirical evidence from China, *Ecological Indicators*, Vol. 156, 111176. <https://doi.org/10.1016/j.ecolind.2023.111176>
- Tilova, U. D. N., Mardiatno, D., & Marfai, M. A. (2024). Transgresi dan Regresi Garis Pantai dari Tahun 2014-2023 dengan Menggunakan DSAS di Wilayah Kepesisiran Kabupaten Kulon Progo Yogyakarta. *Jurnal Penelitian Geografi (JPG)*, 12(1), 38-46. <http://dx.doi.org/10.23960/jpg.v12.i1.28562>
- Wang, S., Wang, J., and Liu, X. (2019). How Do Urban Spatial Structures Evolution in the High-Speed Rail Era? Case Study of Yangtze River Delta, China. *Habitat Int.* 93, 102051. <https://doi.org/10.1016/j.habitatint.2019.102051>
- Yan, X., Liu, Y., Sun, H., Li, J., & Yang, H. (2024). Spatiotemporal impacts of metro network structure on land use change. *Journal of Urban Management*, 13(2), 183-200. <https://doi.org/10.1016/j.jum.2024.04.002>
- Yunus, H. S. (2000). Struktur tata ruang kota. Yogyakarta: Pustaka Pelajar.
- Zhou, L., Dang, X., Sun, Q., & Wang, S. (2020). Multi-scenario simulation of urban land change in Shanghai by random forest and CA-Markov model. *Sustainable Cities and Society*, 55, 102045. <https://doi.org/10.1016/j.scs.2020.102045>

