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Analysis of Land Use/Land Cover Changes 2005–2020 Jagorawi Highway Corridor

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ABSTRACT

Infrastructure development has both negative and positive impacts on the surrounding area. Economics growth, improved living standards, education levels, and easy access are the positive impacts of infrastructure development, meanwhile, it also has the consequences on the natural-resource use and environmental impacts from unsustainable consumption and socio-economic consequences for people around the developed areas. With the currently limited land, management needs to be addressed wisely in areas with high demand for land. Infrastructure can be a catalyst for land use change. This study aims to determine land use changes that occurred in 2005, 2010, & 2020 and analyze its driving factors. We used time series data from Landsat imagery taken from Landsat 5 TM (2005 & 2010) and Landsat 8 OLI/TIRS (2020). Visual analysis method was used to identify and classify the eight land use types per each period of Landsat image series. A simple overlay method was applied to determine the effect of the factors of distance from JT Jagorawi, from arterial collector roads, from GT Jagorawi, and from the government center; and population density. The results show that the built-up area increased from 29.72% in 2005, 32.03% in 2010 and 35.82% in 2020. The range distance that has a potential change in land cover is 4 km from JT Jagorawi & GT Jagorawi; 1 km distance from arterial and collector roads; 7.5 km distance from the government center with a population density of < 5,000 to 10,000 people km^{-2}.

Introduction

A vital infrastructure will have a positive impact on the economy, generate new jobs, reduce the per capita poverty rate [1,2], accelerate mobilization, increase the efficiency of the flow of goods and services [1,3,4] and can reduce the price gap in Indonesia [5]. According to Crescenzi and Pose [6], infrastructure is crucial for the development of a growing population. Infrastructure development has resulted in significant enhancements in connecting diverse regions, particularly economic growth centers and integrated economic areas [7]. Since 2014, 28 toll roads with a total length of 1,088.79 km of main roads and 1.56 km of access roads have been inaugurated [8]. Based on national planning, 13,432 km of national roads, eight dams, and additional infrastructure are still under construction. In the same year, it was anticipated that the Trans Java Toll Road would stretch from west to east [5].

Compared with 1975, when only 750 km of road infrastructure was constructed, it is anticipated that 1,850 km of toll road infrastructure will be constructed in 2019. The funding scheme was between corporations and the government, with 41.3% coming from the central government, 22.2% from State-Owned Enterprises [SOEs], and the remaining 36.5% from individual/private sources. The annual increase in infrastructure investment has ramifications for Indonesia's massive growth. Databoks notes that the infrastructure budget in 2010, 2015, 2020, 2022, and 2023 in Indonesia, respectively, is 86 trillion, 290.3 trillion, 307.3 trillion, 363.8 trillion, and 392 trillion rupiahs. This indicates that several regions in Indonesia have experienced significant

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landscape changes. A landscape is defined as a region with multiple heterogeneous components that comprises diverse ecosystem types that interact with each other [9]. In addition, air pollution and noise pollution have negative effects on the development of toll road infrastructure [7]. The results of the population census from the BPS [10] record the population growth rate for the 1990–2000 period (1.44%), 2005–2010 period (1.49%), and 2010–2020 period (1.25%). As population increases, so does the need for land and accessibility.

The Jagorawi Toll Road (JT Jagorawi) is the first toll road infrastructure in Indonesia. Connecting DKI Jakarta, Bogor City, and Ciawi. The construction of JT Jagorawi was intended to promote equitable development and regional growth. JT Jagorawi has contributed to the Jabodetabek's development. Infrastructure does not always resolve these problems. Every development must have both negative and positive effects on ecological, social, and economic factors either directly or indirectly. As a result of the rapid pace of economic development, many development projects sacrifice productive land, creating a dilemma between maintaining food security and the need for space. If not mitigated as soon as possible, uninformed development will have negative effects on natural preservation and disturb ecosystem stability. JT construction improves accessibility and provides strategic value. Private land use is primarily driven by economic considerations, which create opportunities to convert undeveloped land into developed land. Therefore, further research is required to evaluate the dynamics of land use in the vicinity of JT Jagorawi and the degree of potential change influenced by social and spatial factors. The objective of this study was to investigate the factors influencing changes in land cover surrounding Jagorawi in 2005, 2010, and 2020.

Materials and Methods

Study Area

The scope of the research encompasses 59 km of JT Jagorawi, along with a 5 km buffer zone that traverses six administrative areas (South Jakarta, East Jakarta, Bekasi, Depok, Bogor City and Bogor Regency). JT Jagorawi encompasses 37 Districts, 327 Villages, and 15 Gate Tolls (GT) that are continuously being added. In this study, spatial datasets were analyzed in the Environmental and Spatial Analysis Laboratory, Department of Forest Resource Conservation and Ecotourism, Faculty of Forestry and Environment, IPB. The research period was from November 2022 to January 2023. Figure 1 illustrates the study location.

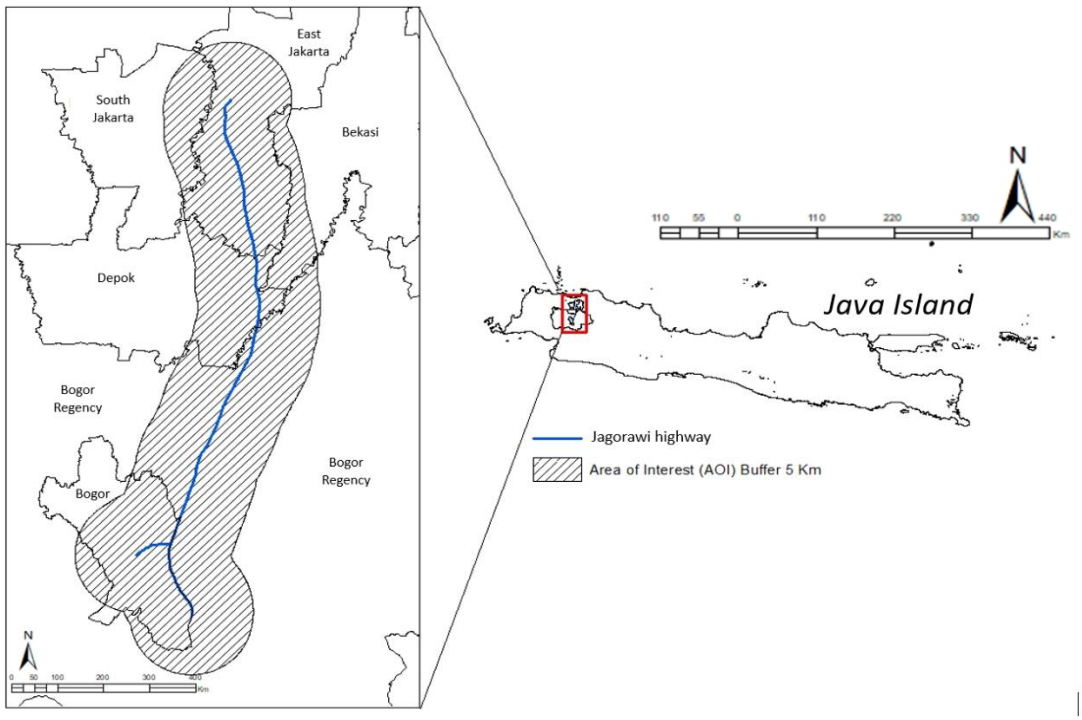

Figure 1. A map of research sites.

Data Collection

Primary data were collected by downloading Landsat imagery from the USGS (http://glovis.usgs.gov/ accessed on 29 March 2021) at path/row 122/64 and 122/65 in 2005 and 2010 (Landsat 5 TM) and 2020 (Landsat 8 OLI/TIRS) with minimum cloud coverage. Available to download map of the research area from BIG (http://tanahair.indonesia.go.id/ accessed on 12 April 2021). Population data obtained from the *Kecamatan dalam Angka* for each District from BPS. Collect actual points of the Gate Toll and Government Center with the help of Google Earth.

Data Analysis

The analysis of the research data consists of two parts: (1) identifying changes in land cover in 2005, 2010, and 2020; and (2) analyzing the driving factors of changes in land use and the socioeconomic impacts on the communities surrounding JT Jagorawi. The phase begins with preprocessing, which consists of layer stacking, geometry correction, and image cutting (clips). Next, road and administrative information were processed to obtain the area of interest (AoI). The image is then clipped using JT Jagorawi with a 5 km buffer created by this approach. To facilitate the interpretation of land cover, a classification with RGB 543 specifications is used. The supervised classification is based on the interpretation of size, hue, pattern, texture, and color. The land use classes observed were built-up area (BUA), high vegetation (HV), dry land agriculture (DLA), wetland agriculture (WLA), uncovered area (UA), shrubs (SB), grass (GR), and water bodies (WB). The visual interpretation procedure utilizes high-resolution imagery, specifically from Google Earth. Evaluation of interpretation accuracy or suitability based on an accuracy or suitability test. There were two accuracy tests: Overall Accuracy (OA) and Kappa Accuracy (KA). The calculation was performed using Wijaya's method [11], specifically the confusion matrix principle. These interpretation results, which meet the standards, can be utilized for further investigation. Analysis of land use/land cover changes from 2005 to 2010 and from 2010 to 2020. The origin of the land can be determined by superimposing a land-cover map for a specific year. The second stage of the analysis process is overlay with influential factors, namely the distance from/to JT Jagorawi, arterial and collector roads, gates toll, government centers, and the population density factor in 2005 and 2020.

Results and Discussion

Time Series Analysis of Land Use/Land Cover

According to the results, LTB, LTA, PLK, and SB dominated the land cover types in 2005, 2010, and 2020, respectively. Detailed results are shown in Table 1 and visually on the land-use map (Figure 2). The expansion of land conversion around JT Jagorawi is indicated by the increase in the area of the LTB, which can be seen in Table 1.

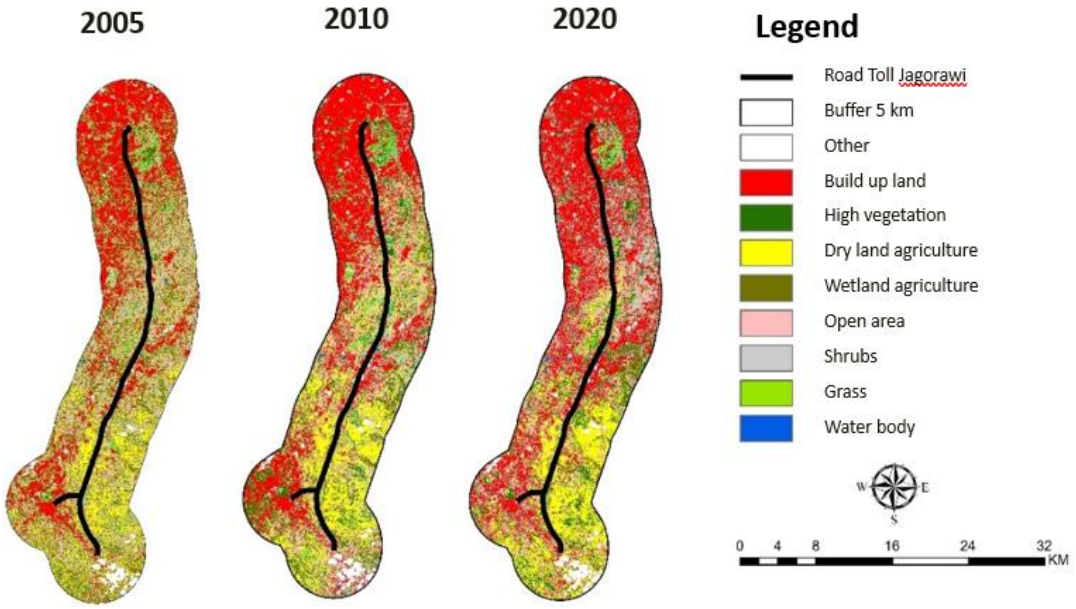

Figure 2. Land use/land cover 2005, 2010, and 2020.

Table 1. Matrix of land area and land cover percentage.

LULC	2005		2010		2020	
	ha	%	ha	%	ha	%
BUA	16,215.93	29.72	17,477.19	32.03	19,542.78	35.82
HV	5,898.60	10.81	5,526.00	10.13	6,410.07	11.75
DLA	7,858.62	14.40	9,815.31	17.99	8,512.56	15.60
WLA	3,617.01	6.63	5,743.53	10.53	3,894.75	7.14
UA	11,021.76	20.20	10,078.83	18.47	12,057.48	22.10
SB	8,663.04	15.88	4,471.74	8.20	2,666.43	4.89
GR	864.90	1.59	1,262.52	2.31	1,013.13	1.86
WB	422.82	0.77	187.56	0.34	465.48	0.85

BUA = build-up land, HV = high vegetation, DLA = dry land agriculture, WLA = wetland agriculture, UA = open land, SB = shrubs, GR = grass, WB = water body.

The presence of UA, DLA, and SB in close proximity to a region dominated by BUA and with a relatively large area is indicative of the suburbanization that occurs near JT Jagorawi. UA and SB, which serve no particular purpose, fall under the category of abandoned land or unproductive land, also known as idle land. According to several previous studies, rural land is associated with suburbanization and development in the surrounding area. Abandoned land is land that is not cultivated and not utilized according to the circumstances, nature, and purpose of granting rights or the basis of their control [12]. This action is not prudent and constitutes an obligatory breach. The existence of idle land hampers development programs that are vulnerable to food security and national economic security. In addition, socioeconomic access to the community is restricted, particularly for farmers on land, and the sense of justice and social harmony is disrupted.

Abandoned land may result from urban expansion or urbanization. Suburban areas, which are expected to grow, attract speculators to buy local people's agricultural land at relatively lower prices, are easy, and are large in area [13,14]. If the purchaser is a developer, the land is subdivided into lots and sold as housing with minimal structure. The resulting margin is greater than the land purchase price. Consequently, there will be settlements on the city's outskirts and suburbanization. Typically, these locations are remote from the arterial and collector roads. The provision of fuel subsidies and ease of ownership of vehicles (motorcycles and cars) contribute to urban sprawl because developers request the government to repair or construct access roads. Idle land exists in several developing nations where the agricultural sector is a primary source of income. Similar to Indonesia, rapid urbanization in Nigeria and Ethiopia has caused farmers to lose access to land that has changed ownership. This situation makes farmers susceptible to poverty and compromises food security [15,16].

This occurred around JT Jagorawi in 2005 to 2020, as indicated by the changes in land use preceding 2005 to 2020. In 2005, abandoned land that had been detected as SB was cleared and it was detected as a large UA. The land was developed as a residential property. According to information obtained from observations using historical imagery features on Google Earth, SB gradually shifted to UA and then to BUA over the succeeding decades. In addition, a small portion was used to expand DLA. Figure 3 clearly shows the dynamics of this land use change. The BUA originating from DLA, SB, and UA were substantial, as shown in Table 2.

Table 2. Land use/land cover change on 2005–2010 and 2010–2020.

Land use/land cover change	Area (ha)	
	2005–2010	2010–2020
BUA – BUA	14,216.8	14,775.80
HV – BUA	178.29	202.68
DLA – BUA	118.89	553.05
WLA – BUA	113.85	375.57
UA – BUA	2,506.86	3,148.65
SB – BUA	287.82	368.91
GR – BUA	12.6	110.43
WB – BUA	42.12	7.65

BUA = build-up land, HV = high vegetation, DLA = dry land agriculture, WLA = wetland agriculture, UA = open land, SB = shrubs, GR = grass, WB = water body.

Several factors cause fluctuations in the DLA region, including the expansion/contraction of land area, the difference between the time when Landsat imagery data were downloaded, and acquisition time. The variance in download time affects the prevailing season on land. The growing season of the land may cause

DLA expansion and WLA reduction or vice versa. Because WLA can change its function to that of DLA if necessary and adapt to the weather (rainy/dry) and season (summer/winter), WLA is a versatile resource. Some cases were converted to BUA. Therefore, an additional analysis is required to improve the precision of the measurement of this dry land agricultural area.

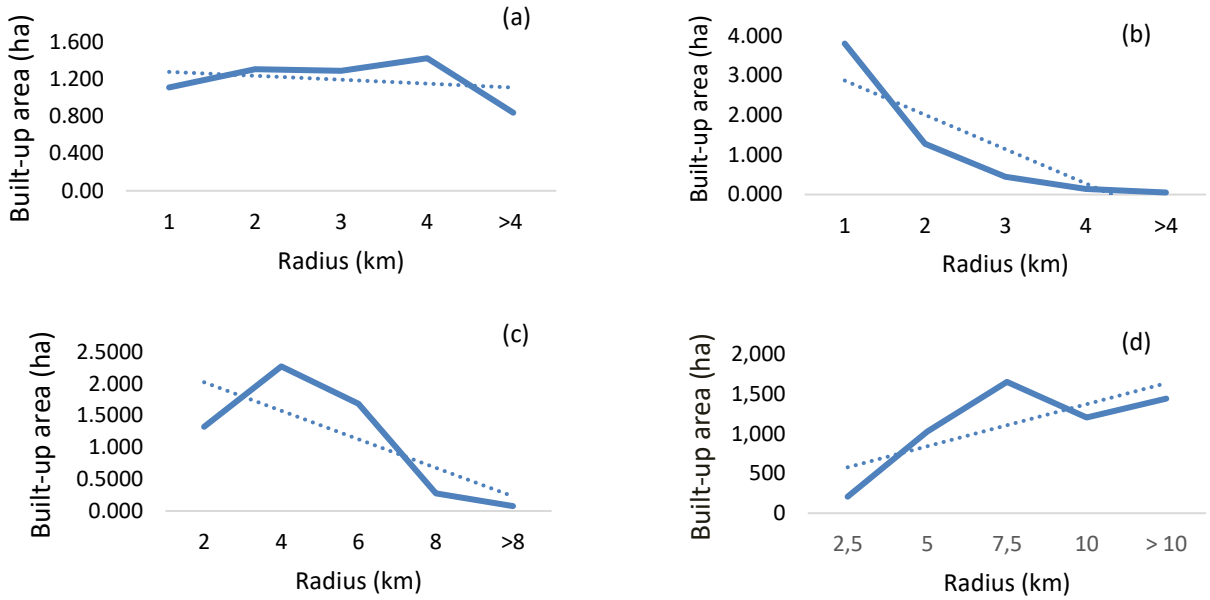

Figure 3. Land use/land cover change determining factors.

Land Use/Land Cover Change

Changes in land use and land cover were divided into two timeframes: 2005–2010 and 2010–2020. Based on the results of the release closing analysis, releases surrounding JT Jagorawi experienced dynamic changes in 2005, 2010, and 2020. Figure 3 demonstrates that BUA is land cover that experiences a constant increase in area, whereas SB tends to experience a significant decrease in area throughout each period. DLA and WLA exhibited concurrent fluctuations. The growing season and climate of the region influence this. Figure 3 depicts the dynamics of the changes in land area.

The increased demand for land is a factor in the growth of the LTB. The reason for this land use is intimately tied to local economic and social communities. A location is more likely to experience urbanization when there is reasonably solid infrastructure present, as the community's economic standing and population rise. According to Law 20/2010, regarding the Main Provisions of Urbanization, urbanization is the conversion of villages into cities that encompass the region and its residents. The other aspects of urbanization include the rise in nonagricultural employment in rural areas [17–20], the expansion of settlements into cities [21], and the spread of socioeconomic, psychological, and cultural influences on rural areas. In Table 2, the number of UA conversions originating from SB, DLA, and UA indicates the formation of suburbanization.

This research focuses on land cover changes to BUA as a representation of the presence of industry and settlements in the land surrounding JT Jagorawi. The information in Table 2 was obtained using this data analysis. The UA represents the most significant change in the BUA per period. This phenomenon was clearly observed during the study period. UA is a category of land that is devoid of vegetation and structures (roads or buildings). Large field dotted with residential and industrial plots. This indicates that land was prepared for BUA use. In addition to external factors, JT Jagorawi has undergone many changes, such as the construction of a toll gate at multiple locations that year, which has contributed to the change from UA to BUA. The area of UA converted to BUA has increased from 2,506.86 ha in 2005–2010 to 3,148.65 ha in 2010–2020. The construction of the Bogor Ciawi Sukabumi (Bocimi) toll road, which is located within the 5 km buffer, was one of the reasons for the expansion during the period 2010–2020. Development converts enough individuals. Thus, it is possible to conclude that urbanization and suburbanization occurred in the observed areas over the past year.

The significant amounts of UA, SB, and GR that have been changed to BUA strongly suggest that this property has several idle lands. This consumption was precipitated by increasing demand for land and population growth, particularly because of urbanization, which has led to urban density and urban sprawl. Mujiandari [22] defined urban sprawl as a phenomenon that arises as a result of the rapid growth of cities with limited land, causing urban development to stretch to the perimeter. Changes in the transportation habits of metropolitan areas, notably a greater reliance on motorized vehicles as the only mode of movement, are indicative of urban expansion. This is because new residential neighborhoods built on abandoned land are inaccessible via arterial and collector roads, and there is no public transportation, necessitating the use of private automobiles. This occurs in most of Jabodetabek's suburban communities.

Urban sprawl is characterized by an BUA pattern of single-use zoning [23]. Because there are too many and they are branching, it is difficult to disentangle the effects of this urban sprawl. related to land and automobile ownership policies. According to Ardiwijaya et al. [13] urban sprawl can contribute to more complex problems in the long run, including reductions in water and air quality owing to transportation and industrialization. Urban sprawl is currently occurring in the Greater Jakarta region, which is also a commuter region that contributes to the growth of the BUA. Under certain conditions, evaluation of the strategic potential of land in the region is required. JT Jagorawi's development transformed this region into an urban sprawl.

Land Use/Land Cover Change Determining Factors

The purpose of the factor analysis was to identify the impact of JT Jagorawi on land use changes. These data can be used as a starting point to reduce urban sprawl. As shown in Figure 3a, this trend diminishes with increasing distance. In contrast, the area with the largest surface area was 4 km. This difference is due to the 1 to 2 km radius, which is still within the private and exclusive JT Jagorawi region. Utilize JT Jagorawi services with various infrastructural facilities as outlined in Government Regulation 15/2005 pertaining to Toll Roads. Within a radius of 4 km, there are public places integrated with public roadways (arterials and collectors), thereby increasing the BUA area. Therefore, there is a high possibility of land change within a 4 km radius of the toll road. According to the findings of Ariyanda and Khorunurrofik [24], there is a strong relationship between a household's employment sector, income level, health, and education. Additionally, households near toll roads have higher incomes than those far from toll roads [25].

Primary highways are road network systems that facilitate the distribution of products and services for the development of all areas at the national level by linking all distribution service nodes in the form of activity centers [Law 34/2004 concerning Roads]. The aspect that has the greatest impact on a city's growth is its roads [20]. As indicated in Fajarini et al. [19], it is believed that arterial and collector roads can influence land transformation. The closer the land is to the arterial and collector highways, the higher the possibility of land alteration, as indicated by the trend in Figure 3b. At a radius of 1 km, the BUA expands; however, at radius of 2 km and 3 km, it is substantially smaller than the radius of 1 km. These data also indicate that the majority of the Jabodetabek region is within 5 km of primary (arterial and collector) roadways [20]. According to previous research by Aljoufie et al. [26] and Ji et al. [27], changes in land use and population density become more intense as they move closer to the road.

JT Jagorawi is provided with 15 GT that are regularly built. The toll gates include Ciawi, Ciawi 2, South Bogor, Bogor, South Sentul, West Sentul, Citeureup, Keranggan, Gunung Putri, Cimanggis, Cisalak, Cibubur, Hamlet 3, Pasar Rebo, and Taman Mini Ramp. GT, which can contribute to urbanization, such as development and land conversion, is one of the major causes of urban sprawl [28–30]. The largest LTB area is located within a 4 km radius of the GT. Building JT necessitated the development of connection lanes that connect the GT to the arterial and collector routes. GT is appropriately connected to arterial and collector roads within a 4 km radius; therefore, it has the ability to alter land use more widely than other radiuses (Figure 3c). The distance from/to GT Jagorawi within a 4 km radius has an effect on changes in land usage. According to Aditya and Husna [31] on GT Sentul Selatan 1 and Sentul Selatan 2, the development of a 2 ha area with a 4 km radius and a 5 km extension from the road corridor occurred. According to previous research, GT has a significant impact on physical development and land conversion in the region [28–30,32–35].

One important factor is the distance from or to government sites, as these government points are typically located near economic areas and other mobility points. According to the observed analysis intervals, the distance from/to the governmental center has a greater impact with a radius of 7.5 and > 10 km (Figure 3d). According to Dwinanto et al. [20], the distance between cities and government headquarters in the Greater Jakarta region ranges from 5 to 10 km, hence 7.5 km falls within that range. This toll road will serve as an alternate route to public highways that prioritizes convenience and can accommodate high-mobility, long-distance traffic flows.

To plan the construction of toll roads, numerous factors are considered, including the availability of sufficient land. This is because JT is not located near roads. The distance from/to the center of the government indicates that neighboring regions have evolved significantly. Especially in the center of the government, which is also the focus of regional development, the combination of strong population growth and increased development has resulted in a congested population. Thus, development extends away from the central government and Jagorawi. A radius of up to 7.5 km from the government center has a substantial impact on development.

In addition to spatial variables, population density is one of the primary causes of land use change. Urban sprawl phenomena arise because the larger the population, the lower the population's carrying capacity. Based on the results of an examination of the population distribution in 2005 and 2020, it was determined that there is a disparity in the influence of population distribution on changes in urban land use. In 2005, the change in the extent of built-up area was greatest in regions with a population density of less than 5,000 people km^{-2}, or 2,255.22 ha. The results are shown in Figure 4, respectively.

With a population density of 10,000 people km^{-2} and total area of 2,249.94 ha, land changes have occurred in 2020. Comparing Figure 4a and 4b reveals that the added load influences the growth of urbanization and changes in the built-up area cover. It is expected that the presence of toll roads in rural areas will cause changes in land use at a population density of 10,000 people km^{-2} in 2020. In addition, population density regions of 10,000 people km^{-2} were strategically positioned. Near the arterial and collector road infrastructure, populated centers, economic centers, and government centers.

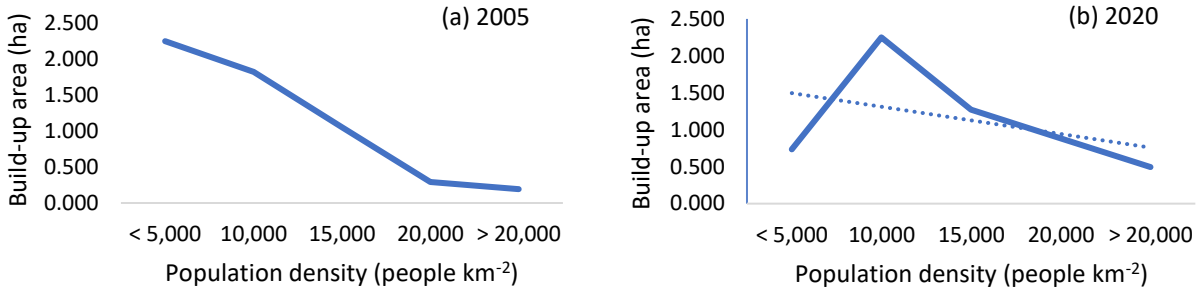

Figure 4. Area based on population density.

Conclusions

BUA, UA, DLA, and cover categories that dominant in 2005, 2010, and 2020, and SB. The area of BUA has continued to increase from 2005 to 2020, namely 16,215.93 ha (29.72%); 17,477.19 ha (32.03%); and 19,542.78 ha (35.82%). This is evidence of urbanization and suburbanization in this region, which formerly consisted of undeveloped territories. Change to BUA in 2005, 2010, and 2020, with the majority of converted UA covering 2,506,86 ha (2005–2010), and 3,148.65 ha (2010–2020). The effect of JT Jagorawi on land-use change is dependent on the distance from/to arterial and collector roads; the closer to the arterial and collector roads, the greater the possibility of land-use changes. Compared with distances greater than 1 km, a radius of 1 km has the largest area. Indirectly, the factors of distance from/to JT Jagorawi and distance from/to GT Jagorawi also play roles. Both GT and JT were merged with arterial and collector highways at 4 km because both GT and JT are connected to arterial and collector roads. The distance from/to the government center is 7.5 km, which contains a large LTB. Due to the effect of JT Jagorawi, these characteristics denote territories with a high potential for change. Consequently, land use can be mitigated within the scope of these criteria.

Author Contributions

TPKW: Conceptualization, Software, Writing & Editing; **LBP**: Conceptualization, Methodology – Review & Editing, Supervision; **YS**: Review, Editing & Supervision.

Conflicts of Interest

There are no conflicts to declare.

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