Relationship Between Population Density and Land Cover Change in Kartasura Sub-district Using Built-Up Index (NDBI)

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Abstract. The population density that occurs in a region can usually cause many problems to occur in the region, one of which is land cover change from vegetation to land that will later be built up. Kartasura Sub-district is a district in Sukoharjo regency that is strategically located in the city area, which means that many issues could develop there. The purpose of this study was to determine the relationship between population density in Kartasura Sub-district and land use changes that occurred in 2010 and 2021. This study employed the Nomalized Difference Built-up Index (NDBI) with Landsat 7 and 8 images obtained from *Google Earth Engine,* and population data were taken from the Statistics Indonesia (BPS) in figures for Kartasura Sub-district in 2010 and 2021. Determining the relationship between population density and changes in non-building land and buildings used variable correlation analysis. The result of this study is the increase in population density every year, despite the decrease in some villages in 2021 due to a factor and the comparison of building classifications in 2010 and 2021. Thus, it is very clear that many changes occurred in 2021, from vegetation land to building land. Overall accuracy (OA) is 92%, and the result of the relationship between the number of residents and building changes is 0.398, which means a positive effect.

Keywords: Population Density · NDBI · Land Cover · Building Changes · Kartasura Sub-district

1 Introduction

Population growth in Indonesia is currently experiencing a very rapid increase, resulting in increased population density. High population density rises some problems, such as a surge in settlements that cause a lot of land to be converted into buildings. Population density is the ratio of a large population to a relatively narrow area. The uneven distribution of the population, which has an impact on population quality, is typically the cause of the problem of population density. The high population growth will also affect the increasing pattern of dense settlements and have a social impact on the community (Arsandrie, 2018).

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Population density can be due to urbanization—an increase in population in urban areas—so it can trigger problems in the development of infrastructure and cause environmental problems (Saini, 2021). The increasing number of people over time can also affect changes in land cover, such as shifts or changes in land that was originally non-building to building. It could be due to human activities (Nadira et al., 2019).

Kartasura Sub-district is one of the sub-districts in Sukoharjo Regency and is strategically located in an urban area, which has potential for the rate of economic growth and is the center of activity, thus affecting the population density and land use (Anisah et al., 2018). In 2020, Kartasura Sub-district had a population of 11.6053 people with a population density of about 5.577 people per km^2. The number of immigrants, including students and workers for businesses, has an impact on the population density in the Kartasura Subdistrict. This triggers an increase in development, such as houses, boarding houses, shops, and places to eat, which affects land cover changes (Arsandrie, 2018).

Land cover refers to the biophysical characteristics of the Earth's surface in a particular area (such as grass, plants, buildings, etc.) that can be interpreted as objects living on the Earth's surface. Land use is the actual use of land by humans, with encroachment and human interaction on the land surface (Dwiprabowo et al., 2014). According to Gong et al. (2013) and Jia et al. (2014), land cover describes a relationship between natural processes and social processes. For the purposes of modeling and comprehending natural phenomena that take place on the surface of the Earth, land cover can offer crucial information. Land cover data are also used to study climate change and understand the relationship between human activities and global change (Dinas Pertanahan dan Penataan Ruang, 2021).

Maps that are produced using remote sensing techniques can show information about a land cover. The output of a remote sensing system is usually the image being observed. To analyze and interpret an image, it is necessary to extract useful information (Nizeyimana, 2005). Remote sensing will quickly, widely, precisely, and conveniently deliver the data in the form of spatial diversity on the surface of the Earth. Remote sensing for land cover typically uses Landsat satellite data.

Urban dynamics are studied using remote sensing technology, which has observational capabilities to gather up-to-date data. Remote sensing is used to produce data for mapping land changes in a city at different scales (Li & Chen, 2018). The land change method can use the Normalized Difference Built-up Index (NDBI) variable due to its quick and objective service in mapping built-up areas (Hidayati et al., 2018).

There have been many studies examining land cover changes using remote sensing that can affect the environment in urban areas (Patra et al., 2018). The existence of urbanization indicators in urban areas causes changes in surface temperature (e.g., geothermal effects) (Singh et al., 2022) and climatic parameters due to the use of vegetation in urban areas (Ibrahim, 2017). The study used remote sensing and geographic information systems and took advantage of the impact of urbanization on a land cover that exists in the research city.

This study aims to determine changes in land cover by considering the changes in building and non-building areas associated with population density in the Kartasura Sub-district. The research was conducted in 2010 and 2021. This study was conducted due to a relatively small amount of research discussing the relationship between the number

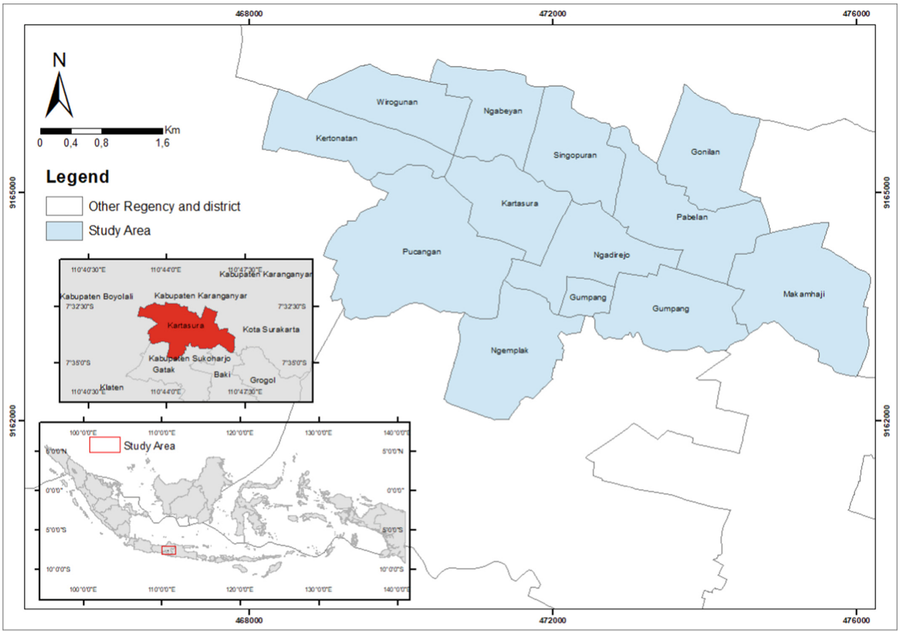

Fig. 1. Research Location.

of residents and the conversion of non-building land into building land. The surge in population due to urbanization can trigger a reduction in green areas to meet the needs of the community. Using geographic information systems and remote sensing, this study shows a decrease in non-building land cover converted into buildings and is related to population density.

2 Methodology

2.1 Research Location

The research was conducted in Kartasura Sub-district in Sukoharjo Regency (Fig. 1). The total area of Kartasura Sub-district is about 1923 ha, with an altitude of 121 m above sea level. Kartasura Sub-district is divided into 12 villages, 2 sub-districts, 116 RW, and 441 RT. Viewed from its strategic location, Kartasura Sub-district is bordered by Karanganyar Regency to the north, Surakarta City to the east, Gatak Sub-district to the south, and Boyolali Regency to the west. The distance from Kartasura Sub-district to the city center of Sukoharjo Regency is approximately 23 km. A map of the research location in Kartasura Sub-district is in the following.

2.2 Research Data

The data used in the study were secondary data, which were obtained indirectly (Table 1). Secondary data can be from previous studies, population data from the Statistics

Table 1. Research Data.

Data	Source	Method
Population in 2010 and 2021	Statistics Indonesia of Kartasura District in 2010 and 2021	Temporal
Population Density	Statistics Indonesia of Kartasura District in 2010 and 2021	Temporal
2010 Landsat 7 satellite imagery	Google Earth Engine	NDBI
2021 Landsat 8 satellite imagery	Google Earth Engine	NDBI

Indonesia figures for Kartasura Sub-district in 2010 and 2021, RBI maps, and Landsat 7 and 8 satellite image data obtained from Google Earth Engine. Below is a table of research data used.

2.3 Data Analysis

By cutting the image in accordance with the area being studied, image interpretation can make use of the Indonesian Topographic Map (RBI). To determine the built-up land due to the influence of population density in Kartasura Sub-district, the image transformation using the Normalized Difference Built-up Index (NDBI). NDBI was applied to Google Earth Engine using two classifications: non-buildings and buildings in Arc Map. The data were gathered using the data artifact table. The NDBI itself is an algorithm showing the density of built-up land, and transformations are often used to assess the index of built-up land and surrounding construction elements. NDBI values can be spectrally dependent from mid-infrared to near-infrared, so NDBI can be measured using Landsat 8 image data with bands 5 (near-infrared) and 6 (mid-infrared) (Ibrahim, 2017). The use of these two channels can clearly distinguish a building object from other objects. From the built-up area, NDBI characteristics can be seen: objects will appear higher in the middle infrared channel than the near infrared channel (Zha et al., 2003). Finding NDBI can be done by using the following equation (Fikriyah et al., 2022).

$$NDBI = \left(\frac{(SWIR - NIR)}{(SWIR + NIR)} \right) \tag{1}$$

where:

SWIR:reflection of mid-infrared rays

NIR:reflection of near-infrared light

Accuracy test is the result of the accuracy of the map with the actual appearance. The error matrix or confusion matrix method is commonly used to test accuracy, so the calculations that can be done are producer's accuracy, user's accuracy, overall accuracy, and Kappa index value. The Kappa accuracy test is usually used based on the difference in the actual level of conformity with the error matrix. Calculating the Kappa accuracy test is shown by the following equation.

$$K = \frac{N \sum_{i=1}^{r} xii - \sum_{i=1}^{r} (xi + x_{+1})}{N^2 - \sum_{i=1}^{r} (xi + x_{+1})} \quad (2)$$

where:

K:Kappa coefficient
N:Total number of observations
R:Number of rows in matrix error
Xii:Number of observations row i column i
X1 +:Total observations on row i
X + 1:Total observations on column i

To determine the relationship between population density and land cover with changes in the shape of non-building land into building land, all data obtained were analyzed using spatial analysis of Geographic Information System (GIS) through digitization on administrative imagery and using correlation analysis. Further details can be seen in Fig. 2.

2.4 Relationship Between Total Population Density and Changes in Building Landforms

The population density on landform change is the analytical unit in this study. The data obtained were analyzed using bivariate correlation so as to test the relationship between population density and changes in existing buildings in the Kartasura Sub-district. The data used two variables, which are the difference between the number of residents in 2010 and 2022. The secondary data used data on the conversions of non-buildings into buildings in Kartasura Sub-district in 2010 and 2022. SPSS application was used to calculate bivariate correlation analysis. There is a guide or decision-making method to analyze bivariate correlation to test the hypothesis of the research itself. P-value (probability or significance value) can be found by considering whether the sig value (2-tailed) is less than the value of alpha. Thus, there will be a correlation between the two variables used and vice versa. The next stage was comparing the calculated R value (Pearson correlations) with the r value in the product moment table. If the calculated r value is greater than the r table, there is a correlation between these variables, and vice versa.

3 Results and Discussion

Kartasura Sub-district is a sub-district in Sukoharjo regency situated in the city area. The geographical location is very strategic to regulate the economy because it is on the main road between provinces and districts, so many migrants from outside the city live in Kartasura. This is due to the existence of several universities; thus, many students from other cities live and settle temporarily in the Kartasura Sub-district. The number

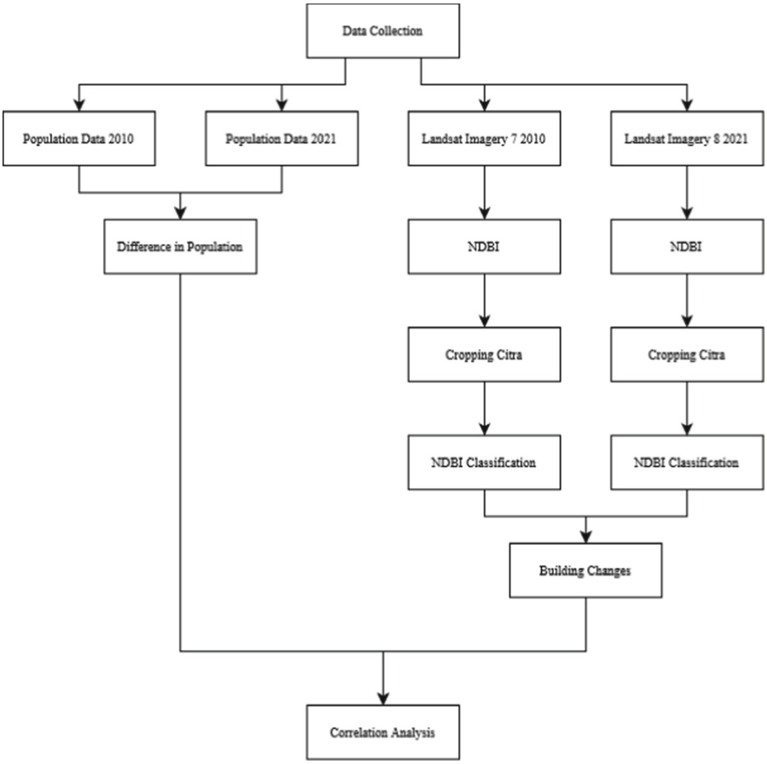

Fig. 2. Research Flow Chart.

of residents in Kartasura Sub-district was approximately 11.6053 people with an area of 2081 ha in 2021. Table 2 shows the population density of the villages in Kartasura Sub-district in 2010 and 2021 by village.

Table 2 shows the difference in population density between 2010 and 2021 is quite large. This can usually occur due to population movements from outside to inside and the fact that many students study around Kartasura Sub-district. There are several villages that experienced a decrease in 2021 due to the COVID-19 pandemic, which caused many migrants, such as students, to prefer returning to their hometowns rather than living around campus. The population density in Kartasura Sub-district is also due to the direct border with the city of Surakarta and the rapid development affected by its urban properties. Rapid urban development attracts job seekers, especially from the surrounding countryside (Dilahur et al., 2001). The rapid increase in population in built-up areas may be the main cause of the social, economic, and environmental changes (Patra et al., 2018). The increase in population density also affects the environment, such as reduced land availability, clean air needs, environmental damage, clean water needs, food shortages, water pollution, and environmental pollution (Ridwan et al., 2021).

Table 2. Total population density (people/km^2) Kartasura Sub-district in 2010 and 2021.

Village	Population Density (people/km^2)	
	2010	2021
Ngemplak	1755	1926
Gumpang	3408	10148
Makamhaji	7406	10950
Pabelan	2856	6772
Ngadirejo	7712	5925
Kartasura	11398	7024
Pucangan	5495	4979
Kertonatan	2757	1961
Wirogunan	2844	3850
Ngabeyan	3686	4935
Singopuran	4741	6001
Gonilan	3367	6266
Sum	4736	5577

3.1 Normalized Difference Built-Up Index (NDBI)

Normalized Difference Built-up Index (NDBI) is commonly used to map an index of buildings in urban areas. NDBI results from built-up areas in Kartasura Sub-district in 2010 and 2021 used Landsat 7 imagery for 2010 and Landsat 8 imagery for 2021. Moreover, there have been many significant changes over the past 11 years. The results of the classification map of non-buildings and buildings in Kartasura Sub-district can be seen in Fig. 3.

The use of NDBI is frequently employed in a variety of studies, including one that examined the impact of population influxes on a region's land area in Central Banjarmasin (Tiara, 2019) and another that employed two places: Bandung and Semarang (Wicaksono et al., 2022). The case study in the Kartasura Sub-District also used NDBI to determine the classification of buildings and non-building areas that will be linked to the number of population densities. This relationship shows the correlation in the research area, where the correlation can possibly be very high, medium, or low. The following is a map of land cover based on two classifications in Kartasura Sub-district in 2010 and 2021 (Fig. 3 and Fig. 4).

The changes in the map above can be seen from the classification results based on changes in buildings in Kartasura Sub-district in 2010 and 2021. The classification is divided into two areas: buildings and non-building areas. The results of changes in the existence of buildings in 2010 and 2021 are very visible. In 2010, the color blue dominates the area, where it can be interpreted as the absence of buildings or the high number of areas used for rice fields or vacant land. Additionally, the red area, which is

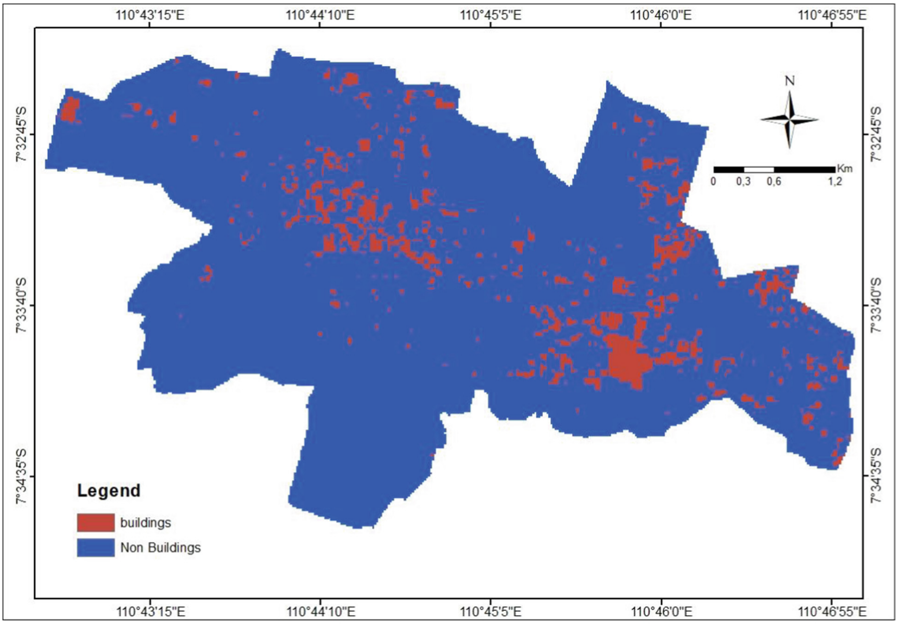

Fig. 3. Map Classification of Normalized Difference Built-up Index NDBI for Kartasura Sub-district in 2010.

still small, indicates the low building index area in the Kartasura Sub-District in 2010. The area of non-building land in 2010 was 1,952.45 ha, while the building land area was 154.16 ha. In 2021, the area of the land increased and decreased, with the area of non-building land decreasing significantly to 1,317.36 ha while increasing to 788.17 ha, where the Kartasura Sub-district is becoming denser as a result of the construction of more buildings.

Kartasura Sub-District changed more significantly in 2021 than it did in 2010. It can be seen in Fig. 4, where the red area is expanding and causing the blue area, such as rice fields or vacant land, to decrease, that non-building areas are declining while dense building areas are increasing. Land reduction can occur due to increased human activities utilizing vegetation or vacant land. There are several factors that affect land changes caused by human activities, such as physical factors and economic factors. Both of these factors affect the socio-cultural conditions of the community, later affecting changes in the land resulting from the increase in population. The increase in population can lead to material needs for the community, causing a high building density that transforms the land that was originally non-building into buildings (Reza, 2021).

The incident that occurred in Kartasura Sub-district can also be attributed to the increase in the number of residents seen with the existence of several universities and academies in Kartasura Sub-district, which caused residents from outside Kartasura to settle and need space to live. The map changes in 2010 and 2021 were also checked using the Kappa accuracy test based on changes in building density.

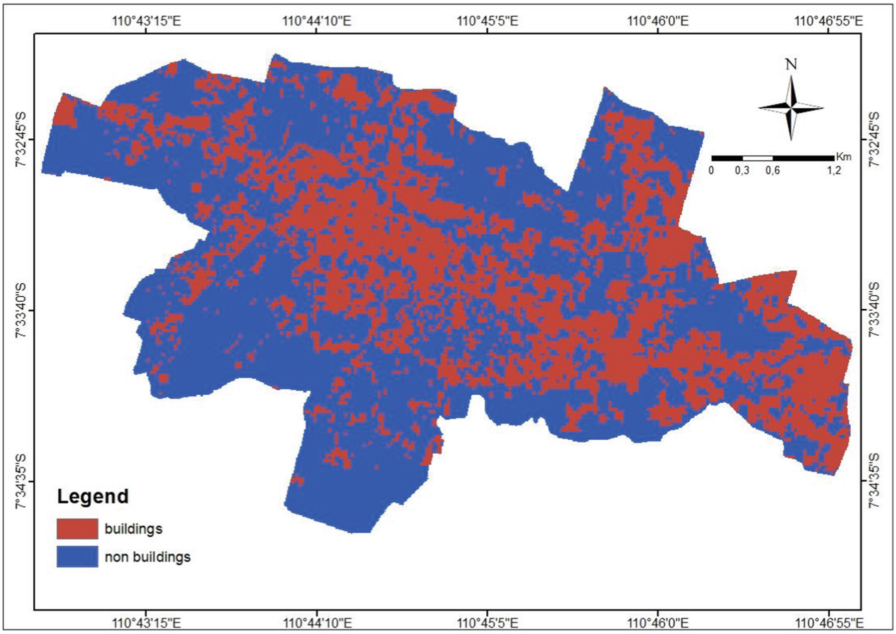

Fig. 4. Map Classification of Normalized Difference Built-up Index NDBI for Kartasura Sub-district in 2021.

Table 3. Degree of conformity in the Kappa coefficient (Landis & Koch, 1977)

Conformity	Trust Level
< 0,4	Low
0,5 – 0,8	Medium
> 0,8	High

The results of the calculations used two classifications seen in the attribute data in Arcmap and were then compared with field surveys to obtain the value of overall accuracy (OA) on the map; field surveys were equal to 92% and the value of the Kappa index was 0.836. Kappa index values are categorized in the high ranks in the level of conformity seen in Table 3.

3.2 Relationship Between Population Density and Building Density

Factor triggering the development of a city is the population growth, (Hermanto et al., 2018) thus this study aims to determine the comparison of a relationship between changes in building land and the difference in the number of residents in 2010 and 2021 in Kartasura Sub-district (Badan Pusat Statistik, 2021) using (Badan Pusat Statistik, 2010) two variables: the area of non-building land changes into building land and the difference

Table 4. Correlation table from SPSS (Statistics Indonesia of Kartasura District in 2010 and 2021 data).

		Population Differences	Change
Population Differences	Pearson Correlation	1	0.398
	Sig. (2-tailed)		0.015
	N	37	37
Change	Pearson Correlation	0.398	1
	Sig. (2-tailed)	0.015	
	N	37	37

in population in 2010 and 2021. Measurements based on correlation analysis examined the relationship between two or more variables without taking independent and dependent variables into account. In addition, the value of correlation analysis is called the correlation coefficient, which can be positive or negative and seen from the correlation results in the SPSS application (Astuti, 2017). Below is the correlation table of the two variables studied (Table 4).

Table 3 states that the significant value of the known output between the difference in the population of Kartasura Sub-district in 2010 and 2021 with building changes in 2010 and 2021 amounted to 0.015. The probability in the correlation analysis was 0.05, where the significant value that occurred was smaller than the probability. Thus, there is a significant correlation between the variable difference in the number of residents and the variable changes in buildings. The value of the correlation coefficient of the difference in the number of residents and changes in buildings was 0.398, where the value of the correlation coefficient (r) is positive, which indicates the correlation of the relationship between the difference in the number of residents in 2021 and 2010 with changes in buildings that occurred in the same year has a unidirectional relationship. Therefore, the greater the value of the population variable, the greater the changes in existing buildings in Kartasura Sub-district. The correlation coefficient (r) value of 0.398 can indicate that there is a weak positive correlation between the variable of the difference in population and the variable of building changes from 2010 to 2021. The two variables have a weak relationship between the number of residents and changes in buildings. However, the rise in population also contributes to an increase in the conversion of non-building land to buildings. Due to the weak relationship between these two variables, there are also other unstudied factors that can cause changes in the building. In order to determine the factors of land area changes to be better understood, future research may use additional, unlisted factors that were not included in this study.

4 Conclusions

The findings demonstrated that, in contrast to land with existing buildings, Landsat analysis using the Normalized Difference Built-up Index (NDBI) in 2010 had more non-building areas where there is still a lot of undeveloped land, rice fields, or vegetation.

This is in contrast to the results of Landsat analysis, where the Normalized Difference Built-up Index (NDBI) in 2021 shows that much vegetation land is reduced and replaced by built-up land such as settlements, food stalls, convenience stores, supermarkets, or individual businesses. Overall Accuracy (OA) is 92% where the results were obtained from the analysis of NDBI and direct-to-field surveys to find the highly accurate changes. In addition, the conclusions of the varied correlation test from the difference in the number of residents in 2021 and 2010 had a positive effect on the change in land use from non-building to building land. The results were 0.398, so the positive effect can be significant if the greater number of residents in the Kartasura Sub-district will affect the increase in land changes that will result in building density in the future.

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