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Analysis of the Influence of Development of Builded Land on the Increase of Surface Temperature Related to the Urban Heat Island Phenomenon in Depok City

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Abstract

Depok City is a satellite city with a strategic location, thus triggering urbanization. Urbanization is one of the causes of the increase in population, in 2011 the population of Depok City reached 1,813,612 people, in 2021 it would become 2,056,335 people. The increase in population and limited urban land resulted in the conversion of non-built land use into built-up land. Built-up land absorbs and reflects heat, so the surface temperature is high. The development of built-up land can result in an increase in surface temperature and trigger the Urban Heat Island (UHI) phenomenon. This study aims to identify the distribution of land cover and surface temperature, analyze the effect of built-up land cover development on the increase in surface temperature, and analyze the relationship between the increase in surface temperature and the distribution of UHI in Depok City in 2011 and 2021. Landsat image data processing methods are used to obtain classifications. land cover using the Maximum Likelihood algorithm, a survey was conducted to validate the results, then the classification of surface temperature was obtained using the Mono-Window Brightness Temperature algorithm. UHI identification is obtained by using the threshold value equation. The effect of built-up land cover development on the increase in surface temperature was tested using simple linear regression. The results showed the development of the distribution of built-up land cover, in 2011 it had an area of 116.98 Km^2 to 150.87 Km^2 in 2021. The distribution of surface temperatures in Depok City in 2011 was dominated by class II surface temperatures with an area of 132.29 Km^2, while in 2021 dominated by surface temperature class IV with an area of 126.03 Km^2. The development of built-up land cover has an influence on the increase in surface temperature by 40.5%. The increase in surface temperature is directly proportional to the increase in the UHI threshold value, the distribution of UHI in Depok City in 2011 has an area of 52.09 Km^2 to 65.63 Km^2 in 2021.

Keywords: *Depok, surface temperature, land cover, UHI*

1. Introduction

The city is the condition of an environment in a strategic and proportional location, economically, socially, and physically from an area (Branch 1995). The city becomes a place as a center for activities such as administrative centers, public service centers, government centers, and economic centers. The city provides all the needs needed by the community, so the city has its own charm in attracting people to come either permanently or temporarily, with the aim of improving living standards or in other words the occurrence of urbanization activities. Depok City is a satellite city of DKI Jakarta, this condition makes this city which is located south of DKI Jakarta as a destination for urbanization. Population growth can be influenced by various factors, one of which is caused by urbanization. The population of Depok City in a period of 10 years has increased, in 2011 it had a population of 1,813,612 people, this number increased in 2021 to 2,056,335. The increase in population will affect the level of population density in Depok City, Depok City has a population density of 9,055 people/km² and will be 10,267 people/km2 in 2020.

Land has an important role in human life which acts as a container for a variety of ecosystems and becomes an important part of the ecosystem, land use can be viewed from the process of interpreting cover from aerial photographs or satellite imagery (Sutanto 1994). Land use can be interpreted in terms of land cover (Giofandi and Sekarjati 2020). The increase in population causes an increase in the need for space or built-up land which is used by residents for housing and carrying out various activities in order to meet their needs. The land owned by the City of Depok is limited so that there are changes in various land uses, especially the use of the majority of vegetated land into the use of built-up land. Dewi and Rudiarto (2013) explain that the need for land designated for development is very strong and complex, while the land area of the city is limited and does not experience development, along with the increasing number of residents and the increasing complexity of economic activities, the need for built-up land tends to increase. In Susanto (2013) vegetation land can absorb CO2 gas and withstand radiation from sunlight, so it can create cool air, and has an important role for urban areas.

The decrease in vegetated land and the development of built-up land in Depok City resulted in an increase in the average surface temperature. According to Khomarudin (2004) built-up land such as cement, concrete, and asphalt are absorbing and reflecting the sun's heat. In a study conducted by Nofrizal (2018), it was stated that the significant development of built-up land resulted in an increase in the average surface temperature in urban areas, or could be said to be affected by UHI. Climate change can occur due to changes in climate elements, changes in climate elements that can be felt directly by humans are surface temperatures, urban areas are susceptible to changes in surface temperatures. Urban Heat Island is a phenomenon that surface temperatures in urban areas tend to be higher than suburban areas, the high surface temperatures are concentrated in the city center and

decrease towards the periphery (Zulkarnain, 2016). The increase in the average surface temperature as a result of the development of built-up land area indicates that the Depok City area is affected by UHI.

Depok City is a satellite city that is the center of urban population activities, so it has a high population or population density level, this is of course directly proportional to the development of built-up land which has an impact on increasing surface temperatures and the UHI phenomenon. In accordance with research conducted by Iqbal et al. (2018), Depok City is the center of economic growth in West Java Province, so there is a condition where the increase in population is directly proportional to the increase in the area of built-up land such as housing and retail, which worsens the quality of space and the environment, which in turn will result in an increase in surface temperature. The condition of Depok City as described above, causes the comfort level of the residents of Depok City to be reduced, this should be a concern for related parties in urban spatial planning in order to minimize the occurrence of UHI. Related to this background, researchers are interested in conducting research with the title "Analysis of the Effect of Developed Land Development on the Increase in Surface Temperature Related to the Urban Heat Island Phenomenon in Depok City". This study aims to identify the distribution of land cover and surface temperature in Depok City in 2011 and 2021, analyze the effect of built-up land cover development on the increase in surface temperature, as well as the relationship between increased surface temperature and the distribution of UHI in Depok City. In its application, this study utilizes remote sensing. using Landsat 7 and Landsat 8 images.

2. Method

The research method used is an image data processing method and a survey method. The land cover classification, surface temperature, and UHI were obtained from the results of Landsat 7 and Landsat 8 image processing. Meanwhile, the survey method was used to test the accuracy of the land cover classification results with a sample of 35 sample points obtained by random sampling method, utilizing available random point tools. in the ArcGIS software. Methods of data collection using primary and secondary data. Primary data in the form of Landsat imagery of Depok City with path 122 row 64 downloaded through the official website, namely the United States Geological Survey (USGS), as a research basis to obtain results of land cover classification, surface temperature, and UHI phenomena. Other primary data is sample data, obtained from surveys through GeoEye imagery on Google Earth Pro software, which is used to test the accuracy of land cover classification results. The supporting data for the research are secondary data in the form of spatial data on the administrative boundaries of the sub-district and city/regency of Depok City, obtained from Indonesia's Digital Geospatial Data by the Geospatial Information Agency. The instrument in this study is the validation test table, while the tools needed are in the form of hardware, namely laptops, and software, including ENVI 5.3, Arc Gis, SPSS, and Google Earth Pro.

Radiometric Correction

Radiometric correction is carried out with the aim of correcting errors in satellite imagery by increasing contrast, so that the recorded object corresponds to the actual condition, in this correction using the Top Of Atmosphere (TOA) and \Sun Angle Correction equations to correct the error reflectance value due to the position of the sun.

Rumus TOA *Reflectance* :

$$\mathbf{p\lambda' = MpQcal + Ap}$$

Keterangan:

pλ'	: nilai reflektan citra
Mp	: konstanta rescalling
Qcal	: nilai piksel (DN)
Ap	: faktor penambah

Rumus Sun Angle Correction :

$$p\lambda = \frac{\rho\lambda'}{\cos(\theta SZ)} = \frac{\rho\lambda'}{\sin(\theta SE)}$$

Keterangan :

pλ	: reflektan TOA dengan koreksi sudut matahari
ρλ'	:nilai refletan TOA tanpa koreksi sudut matahari
θSE	:sudut elevasi lokal matahari (SUN_ELEVATION)
θSZ	: sudut zenith lokal matahari dimana θSZ = 90° - θSE

Land Cover Reclassification

Land cover classification is carried out using a guided classification method, using the Maximum Likelihood equation, sampling is obtained through the Region Of Interest (ROI) determined by the operator, the training area is taken spread over all parts of the image with a minimum of 100 pixels on each land cover. Land cover classification is classified into built up land, vegetated land, water bodies, and vacant land.

Sample Data Processing

Sample data obtained from a survey using GeoEye imagery on google earth software is processed by calculations using a confusion matrix table, and an accuracy test calculation is carried out using the following kappa statistics:

$$K = \frac{N\sum_{i=1}^{k} xii - \sum_{i=1}^{k} xi + * x + 1}{N^2 - \sum_{i=1}^{k} (xi + * x + 1)}$$

Land Surface Temperature (LST) Reclassification

Surface temperature classification is processed using the Mono-Window Brightness Temperature algorithm on the thermal band that belongs to Landsat imagery, Landsat 7 imagery is in Band 6 and Landsat 8 imagery is Band 10 and 11. The surface temperature of Depok City in 2011 and 2021 is classified into 5 grades with intervals of 2.5℃. The following is the LST classification stage:

1. Convert digital number (DN) to –radiance, formula:

$$\mathbf{L\lambda = ML \times Qcal + AL}$$

Keterangan:

Lλ = Spektral Radiansi ToA 2

ML = Faktor rescaling perkalian tiap band

AL = Faktor rescaling adiktif tiap band

Qcal = Nilai digital

2. Converts atmospheric corrected radiance to brightness temperature, formula:

$$\text{[illegible]} = \frac{\text{[illegible]}}{\text{[illegible]}\ln\left(\frac{\text{[illegible]}}{\text{[illegible]}}\right)+\text{[illegible]}} - \text{[illegible]}\ 15$$

Keterangan:

T = Brightness temperature,

ln = Spektral radiansi ToA

K1 = Konstanta konversi thermal tiap band

K2 = Konstanta konversi thermal tiap band

3. Identify NDVI, formula:

$$\text{[illegible]} = \frac{\text{[illegible]} - \text{[illegible]}}{\text{[illegible]} + \text{[illegible]}}$$

Keterangan: NIR = Band infrared dekat, Red = Band merah

4. Calculating the value of the Vegetation Proportion, the formula:

$$\text{[illegible]} = \left(\frac{\text{[illegible]} - \text{[illegible]}}{\text{[illegible]} + \text{[illegible]}}\right)$$

5. Calculating the emissivity value, the formula:

$$\mathbf{E = 0.004 \times Pv + 0.986}$$

6. Converts satellite temperature to surface temperature

$$\mathbf{T = Tb/[1+\lambda \times Tb/c2) \times \ln(e)}$$

Keterangan:

Tb = Brightness temperature

λ = Panjang gelombang

C2 = 14388μm K

Identification of Urban Heat Island (UHI)

The phenomenon of the island of heat or UHI is identified using the following equation for the UHI threshold value by Jatmiko (2015):

$$\mathbf{UHI = T_{mean} - (\mu + 0{,}5\ \alpha)}$$

Keterangan:

UHI = *Urban Heat Island*

T_{mean} = *Land Surface Temperature* (°C)

μ = Nilai rerata *Land Surface Temperature*

α =Nilai standar deviasi *Land Surface Temperature* (°C)

Simple Linear Regression

The effect of the development of the built-up land cover area on the increase in surface temperature in Depok City was tested by a simple linear regression test, which was processed using SPSS software. The equation used is as follows:

$$\mathbf{Y=a+bX+e.}$$

Information: Coefficient a; Constant, Coefficient b : Constant, Coefficient e : Error Value

The analytical method used to analyze land cover, surface temperature, and UHI was carried out using a qualitative descriptive method by explaining the results in the form of distribution maps, tables, and graphs. While the analysis of the influence of the development of built-up land cover on the increase in temperature in Depok City uses quantitative descriptive analysis by explaining the numerical data presented in tables and graphs.

3. Results and Discussion

The results obtained from the Landsat 7 and Landsat 8 image processing include the distribution of land cover, the distribution of surface temperature, and the distribution of UHI in Depok City in 2011 and 2021. While the results of processing linear regression statistical data are in the form of calculating the effect of the development of built-up land cover on increasing surface temperature in Depok City. Depok City land cover classification was obtained from Landsat 7 image processing with recording time on April 22, 2011 and Landsat 8 imagery with recording time on 11 May 2021. Depok City land cover was classified into the following 4 classes, built-up land cover, vegetation land cover, land cover vacant land, and land cover bodies of water. The Maximum Likelihood Algorithm is used to get the land cover classification of Depok City, so that the level of accuracy is obtained as follows, the land cover classification in 2011 has an Overall Accuracy of 91.42% with a kappa accuracy value of 87.21%, while in 2021 it has an Overall Accuracy of 94.28% with kappa accuracy value of 90.14%. The results of the land cover classification of Depok City in 2011 and 2021 have met the criteria based on the digitally supervised digitally supervised multispectral satellite data processing guidelines for the classification compiled by LAPAN (2015), namely the image classification is considered correct and feasible if the result of the Confusion Matrix calculation is not less than 75%. Changes in land cover area of Depok City in 2011 and 2021 can be seen in Figure 1, while the distribution of land cover in Depok City in 2011 and 2021 is shown in Figure 2 below.

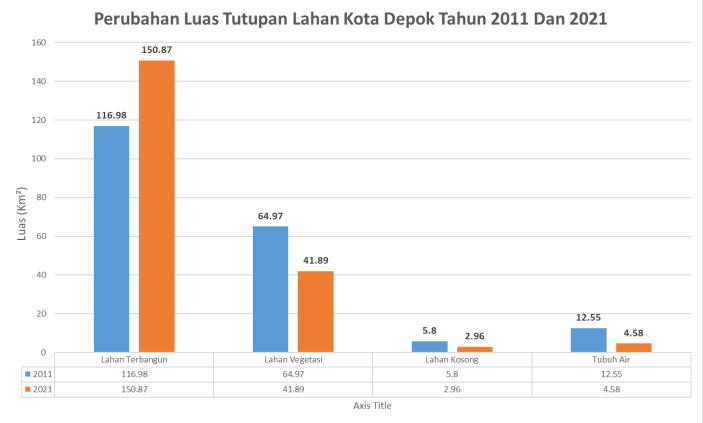

Figure 1. Graph of Changes in Land Cover Area of Depok City in 2011 and 2021.

Source: Data processing, 2022

Based on the graph of changes in land cover area of Depok City in 2011 and 2021 contained in Figure 1 above, it is known that based on the widest order of land cover, Depok City can be sorted as follows: built-up land, vegetative land cover, water body land cover, and vacant land cover, with the composition and a different percentage of area in each year. Built-up land cover is land cover which includes settlements, industrial buildings, roads, railway networks, etc. Built-up land cover has an area and distribution that dominates Depok City in 2011 and 2021. In 2011 Depok City consisted of a built-up land cover covering an area of 116.98 Km2, to 150.87 Km2 in 2021. The development of a land cover area of 33.89 Km2 causes other land cover to decrease in area.

Vegetative land cover can consist of plantations, shrubs, rice fields, fields, and mixed crops. Vegetation land cover is the land cover that experienced the greatest decrease in area due to the development of built-up land cover, but this land cover is the second largest land cover after built-up land cover in 2011 and 2021. Vegetation land cover in 2011 has an area of 64, 97 Km2, to 41.89 Km2 in 2021, or it can be said that there is a decrease in area of 23.08 Km2. The water body land cover consists of lakes, lakes, rivers, and ponds, in 2011 the water body land cover has an area of 12.55 Km2, to 4.58 Km2 in 2021, or there is a decrease in area of 7.97 Km2. Empty land cover is land cover that is natural or non-natural, this land cover is usually in the form of open land that lays red soil without any buildings or vegetation on it (Risma et al., 2012). In 2011 Depok City had an area of vacant land cover with an area of 5.8 Km2, to 2.96 Km2 in 2021 or a decrease in area of 2.84 Km2.

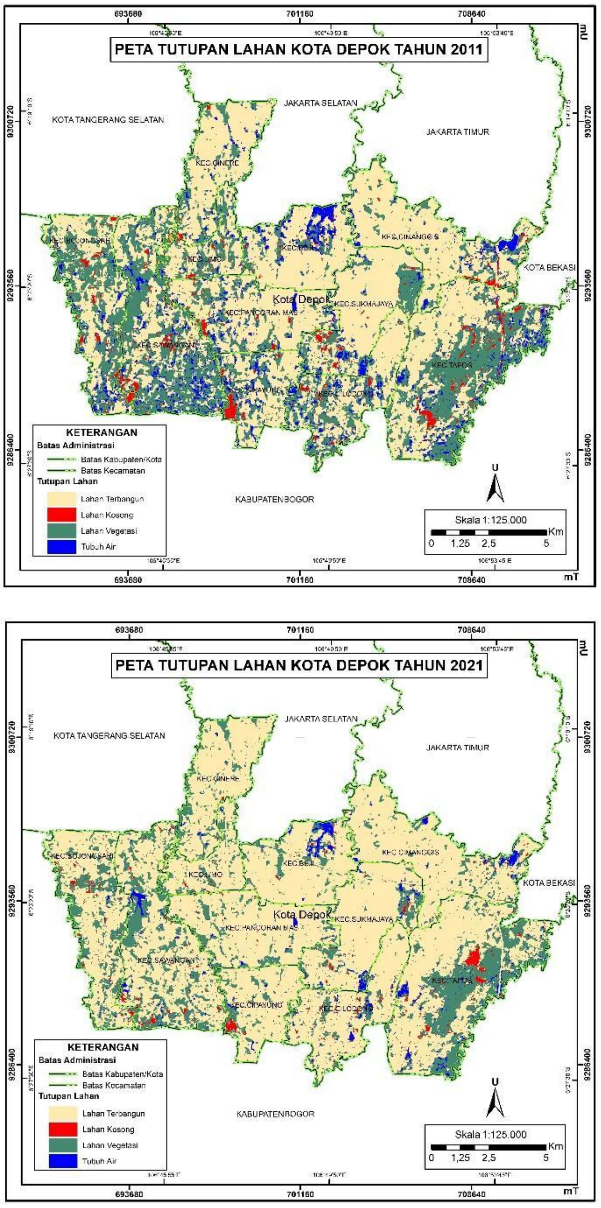

Figure 2. Land Cover Map of Depok City in 2011 and 2021.

Source: Data processing, 2022

Based on the Depok City land cover maps for 2011 and 2021 as shown in Figure 2 above, it is known that built-up land cover is symbolized in beige, vegetation land cover in green, water body land cover in blue, and empty land cover in red. The distribution of built-up land cover has a distribution that dominates Depok City, in 2011 and 2021 it has distribution throughout the sub-district area, but in 2011 it has a dominant distribution in the central and northern parts which are directly adjacent to DKI Jakarta, precisely South Jakarta City and East Jakarta City , such as in the sub districts of Cimanggis District, Pancoran Mas District, Sukmajaya District, Cinere District, and Beji District. Whereas in 2021 the built-up land cover is almost evenly distributed, the dominant distribution is in the central, northern and southern parts of the Depok City area, sub-districts that

have a dominant distribution of built-up land cover almost similar to 2011 but encroaching on Limo District in the north, Cipayung District , and Cilodong District in the southern part of Depok City.

Depok City has a location that is directly adjacent to East Jakarta City and South Jakarta City, which has an impact on the increase in built-up land due to the large number of residents building residences in Depok City with a background close to DKI Jakarta so that it is considered strategic. In accordance with research conducted by Desiyana (2017), Depok City has a location bordering the southern part of Jakarta, since 1990 the population of Depok City has continued to increase, many residents live in Depok City and work in Jakarta City so that the original land of the City Depok, which consists of forests, plantations and agriculture with several lakes and rivers, has turned into a residential area. The city of Depok is a satellite city so it has a high level of population density and indicates the development of built-up land. south of Depok City, such as in Cipayung District and Cilodong District.

The vegetation land cover for Depok City in 2011 and 2021 has a distribution throughout the sub-district of Depok City with a smaller area in 2021. In 2011 it has a dominant distribution in the western, eastern and southern parts of Depok City, namely in Tapos District, Sawangan District , and Bojongsari District. whereas in 2021 there will be sub-districts with a visually decreased distribution of vegetation land cover, including Limo District, Pancoran Mas District, Cipayung District, Cilodong District, and Sukmajaya District, these sub-districts are located in the central and northern parts of Depok City which are close to DKI Jakarta so that a lot of vegetation land cover is replaced by built-up land cover. The distribution of vegetation land cover in 2021 is dominant in the western, eastern and southern parts. The sub-districts with the dominant distribution of vegetation land cover were almost similar in 2011, namely Tapos, Sawangan, and Bojongsari, but with a smaller area. The subdistrict area with the distribution of vegetation land cover is the area bordering Bogor Regency. This is because according to Dani et al., (2017) Bogor Regency has vegetation land use of 89.96% of the total area of Bogor Regency, so that vegetation land cover in Bogor Regency is the dominating land cover. This affects the distribution of vegetation land cover in Depok City, which borders Bogor Regency.

The land cover of Depok City's water bodies in 2011 and 2021 has a distribution in all sub-districts. According to Dewanti & Naryanto (2018), Depok City is fed by two major rivers, namely the Ciliwung River and the Cisadane River, besides that Depok City also has 25 lakes spread across the western, central, and eastern parts. Land cover objects of water bodies that are clearly interpreted on the land cover distribution map of Depok City in 2011 and 2021 include Situ Sawangan which is in Sawangan District, Situ Rawa Besar which is in Pancoran Mas District, Situ Rawa Jemblung which is located in Cimanggis District, Situ Jatijajar is located in Tapos District, Ciliwung River which stretches from the southern part of Depok City to the north. The land cover of the water bodies of Depok City in 2011 had a dominant distribution in the southern and northern parts, such as in Sawangan District, Tapos District, Beji District, Cimanggis District, Cilodong District, and

Bojongsari District. in 2021 it has a distribution that is almost similar to 2011 with a smaller area, but there is a new distribution in Pancoran Mas and Sukmajaya sub-districts. Empty land cover in 2011 and 2021 has a distribution in all sub-districts in Depok City. In 2011 it had a dominant distribution in Tapos District, Sawangan District, Bojongsari District, Cipayung District, Pancoran Mas District, Cimanggis District, and Sukmajaya District. There was a decrease in the area of vacant land cover in 2021, the decrease in vacant land cover was caused by an increase in other land cover areas, mainly built-up land cover in 2021. In 2021, the dominant vacant land cover was spread in Tapos, Sawangan, and Bojongsari sub-districts.

The surface temperature of Depok City was obtained from Landsat image processing by recording during the dry month period. In 2011 using Landsat 7 imagery with a recording time of 22 April 2011 and in 2021 using Landsat 8 imagery with a recording of 11 May 2021. Surface temperature or LST in Depok City is obtained by the mono-window brightness method or equation. The surface temperature classification of Depok City is divided into 5 classes, namely class I (≤ 22.5 oC), class II (22.6 – 25.1 oC), class III (25.2 – 27.7 oC), class IV (27 ,8 – 30.3 oC), and class V (≥ 30.4 oC). The lowest surface temperature of Depok City in 2011 was 20.26 oC and the highest was 32.19 oC, while in 202 it had the lowest surface temperature of 20.42 oC and the highest 33.38 oC.

Figure 3. Graph of Depok City Surface Temperature Distribution in 2011 and 2021.

Source: Data processing, 2022

Based on the graph of the surface temperature distribution of Depok City in 2011 and 2021 which is shown in Figure 3 above, it is known that the classification of Depok City's surface temperature class I in 2011 had an area of 15.44 Km2 and decreased in 2021 to 0.01 Km2, Class II in 2011 it has an area of 132.39 Km2 in 2021 it decreases to 0.25 Km2, class III in 2011 has an area of 49.72 Km2 in 2021 it increases to 55.29 Km2. Class IV in 2011 has an area of 2.74 Km2 in 2021, increasing significantly to 126.03 Km2, Class V in 2011 has an area of 0.01 Km2 in 2021 increasing to 18.72 Km2. The surface temperature of Depok City in 2011 was dominated by Class II surface temperature with an area of 132.39 Km2 while in 2021 it was dominated by Class IV with an area of 126.03. There was an increase in the average surface temperature of Depok City in 2021. Surface

temperature processing is more. Furthermore, it is also possible to find out the average surface temperature of each Depok City land cover, which is shown in Table 1 below.

Table 1. Average temperature of each type of land cover in Depok City in 2011 and 2021.

	Types of Land Cover	Suhu (℃)	
		Year 2011	Year 2021
1	Built-up Land	25,1	29,8
2	Empty land	24,5	29,1
3	Vegetation Land	23,9	27,5
4	Water Body	23,7	27,2
Average		24,3	28,4

Source: Data processing, 2022.

Based on Table 1 above, it is known that the built-up land cover is the land cover with the highest surface temperature in each year, in 2011 it had a surface temperature of 25.1 and in 2021 it became 29.8 ℃. The surface temperature of built-up land tends to be high, according to Khomarudin (2004) this is due to the fact that the soil surface that turns into built-up land absorbs more of the sun's heat and reflects it more. Bare land cover in 2011 had a surface temperature of 24.5℃ in 2021 it increased to 29.1℃. Vegetation land cover in 2011 had a surface temperature of 23.9 ℃ in 2021 increased to 27.5 ℃. The water body land cover is the land cover with the lowest surface temperature compared to other land covers, in 2011 the water body land cover had a surface temperature of 23.7 ℃, this figure increased in 2021 to 27.2 ℃. Sub-districts in Depok City have different land cover compositions, so that it will affect the average surface temperature in each sub-district. The distribution of the surface temperature classifications for the City of Depok can be found in the surface temperature distribution map for the City of Depok in 2011 and 2021 which is shown in Figure 4 below.

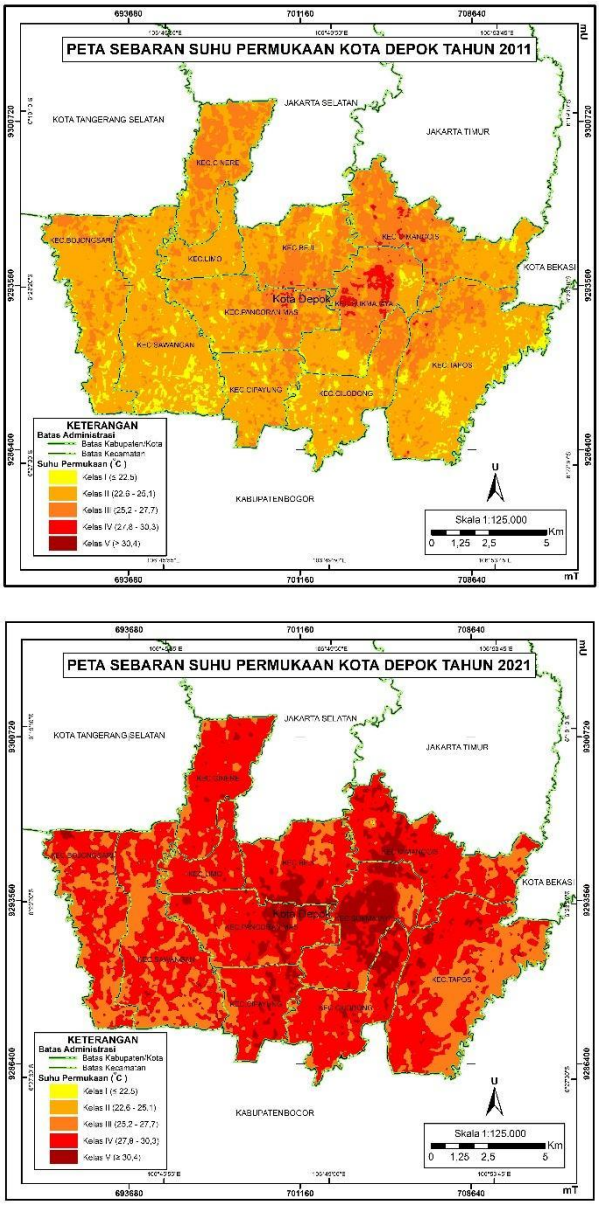

Figure 4. Surface Temperature Distribution Map for Depok City in 2011 and 2021.

Source: Data processing, 2022.

Based on the surface temperature distribution map in Figure 4 above, each surface temperature class is symbolized by a color gradation. The surface temperature of class I is symbolized in yellow, class II is symbolized in light orange, class III is symbolized in orange, class IV is symbolized in red, and class V is symbolized in dark red. The surface temperature of Depok City class I in 2011 has distribution throughout the District, with a dominant distribution in the western, southern and eastern parts of the Depok City area, these districts include Sawangan District, Tapos District, Cilodong District, and Bojongsari District, while for 2021 the area has decreased so that it only has a distribution in the Cimanggis District. Class I surface temperature is a low class surface temperature whose area has land cover with low surface temperature such as vegetation land cover and water body

land cover. The decrease in class I surface temperature distribution in 2021 is due to an increase in the average surface temperature of Depok City in 2021 due to the expansion of built-up land.

Class II surface temperature in 2011 has a nominating distribution, this is because the average surface temperature of Depok City in 2011 was 24.3℃, this temperature value belongs to class II surface temperature. Class II surface temperature in 2011 was dominated by built-up land cover which had an average surface temperature of 25.1℃, this surface temperature class had a distribution in all areas of Depok City sub-district, with a dominant distribution in the west, east and south of Depok City such as Bojongsari District, Sawangan District, Tapos District, Cipayung District and Cilodong District. Whereas in 2021 the area will decrease due to an increase in average surface temperature in 2021, this surface temperature class is only found in Cimanggis District which is located in the north and Tapos District in the eastern part of Depok City. Class III surface temperature classification has distribution throughout the Depok City sub-district with dominance in several sub-districts in the central and northern parts of Depok City, these sub-districts include Cimanggis District, Cinere District, Beji District, and Pancoran Mas District. Whereas in 2021 it will be distributed in all sub-districts in Depok City, with the dominance of distribution in the western and eastern parts of Depok City, such as in Tapos District, Sawangan District, and Bojongsari District.

Class IV surface temperature classification in 2011 has a distribution throughout the Depok City sub-district except for Limo District and Cipayung District, but with a small area. Districts with a dominant distribution include Sukmajaya District, Cimanggis District, and Pancoran Mas District. Whereas in 2021 there will be a significant increase in area, so that class IV surface temperatures have a dominating distribution, with the dominant distribution in the northern, central and southern parts of Depok City, such as in Cinere District, Limo District, Beji District, Cimanggis District, Pancoran District Mas, Sukmajaya District, Cipayung District, Cilodong District, and Tapos District. The increase in class IV surface temperature is caused by an increase in the average surface temperature to 28.4℃ and the development of built-up land cover, in 2021 built-up land cover will have an average surface temperature of 29.8℃, so it is included in the class class IV. In accordance with research conducted by Fawzi, et.al. (2013) the results of their research are that the city of Yogyakarta has a warmer surface temperature than the surrounding area due to the UHI phenomenon which is related to the built-up land cover which has a higher temperature, which ranges from 31 – 37 ℃.

The surface temperature classification with the highest class, namely class V, in 2011 had a distribution in Tapos District and Cimanggis District, with distribution dominance in Cimanggis District which borders South Jakarta City and East Jakarta City. Whereas in 2021 it will be distributed throughout all sub-districts in Depok City, dominant in the central and northern parts of Depok City, such as Sukmajaya District, Pancoran Mas District, Cimanggis District, Beji District, and Cilodong District. Based on research conducted by Raya & Hasibuan (2020), namely the spatial pattern of surface temperatures in Jakarta and its surroundings, areas that are closer to the city of Jakarta have higher surface temperatures because they are dominated by built-up land cover.

The city of Depok has developed a built-up area of 33.89 Km2 and experienced an average increase in temperature of 4.2℃. To determine the effect of the development of built-up area on an increase in surface temperature, Depok City was tested using a simple linear regression test, with the independent variable development the area of land cover built up to the dependent variable, namely an increase in surface temperature. The following are the results of a simple linear regression test in Table 2 below.

Table 2. Simple Linear Regression Results Table.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.636[a]	.405	.395	.36664

a. Predictors: (Constant), Perkembangan Luas Lahan Terbangun

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3.865	.074		52.329	.000
	Perkembangan Luas Lahan Terbangun	.007	.001	.636	6.438	.000

a. Dependent Variable: Peningkatan Suhu Permukaan

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.571	1	5.571	41.445	.000[b]
	Residual	8.200	61	.134		
	Total	13.771	62			

a. Dependent Variable: Peningkatan Suhu Permukaan

b. Predictors: (Constant), Perkembangan Luas Lahan Terbangun

Source: Data processing, 2022.

Based on the calculation results of the simple regression test in Table 2, the correlation value or relationship value (R) in the Model Summary table is 0.636, which means that it follows the classification by Sugiyono (2017) the correlation value between the development of built-up land cover and an increase in surface temperature in the City Depok is included in the strong classification because it has a coefficient interval of 0.60 – 0.799, namely 0.636. the coefficient of determination or (R2) obtained is 0.405, which means that the effect of the development of built-up land area in Depok City on the increase in surface temperature of Depok City is 40.5% while the rest is influenced by other variables of 59.5%, other variables can be as the level of density of vegetation, greenhouse gases or other effects. Similar results were also obtained in research by researchers Andani et al. (2018) who obtained a positive regression coefficient, with a directly proportional relationship, the coefficient of determination (R2) was 0.4355, meaning that there was an effect of increasing the area of built-up land on an increase in surface temperature of 43.55%.

Based on the ANOVA table, it explains the real influence or significance between the independent variables, namely the development of the built-up area on the dependent variable, namely surface temperature. Obtained F count of 41,445 with a significance level of 0.000, meaning that a simple linear regression calculation model can be used to predict the dependent variable, namely an increase in surface temperature because it has a significance value of <0.05. In the coefficient table it

is known that the constant value (a) is 3.865 and the development value of built-up area (b) is 0.007, so the equation is y = 3.865 + 0.0007 x. This equation has a constant positive value, which means that the independent variable, namely the development of built-up land cover, and the dependent variable, namely an increase in surface temperature, has a directly proportional effect or relationship. It can be concluded that if the development of built-up land cover increases, the surface temperature value will also increase. The graph of the simple linear regression test results can be seen in Figure 5 below.

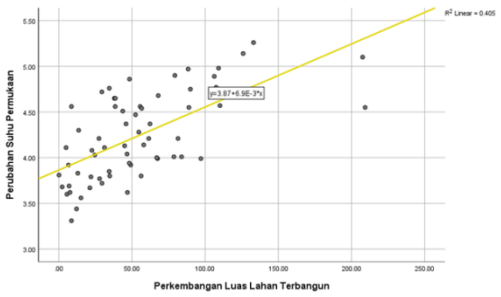

Figure 5. Simple Linear Regression Graph

Source: Data processing, 2022

. *Urban Heat Island is a condition or phenomenon that occurs in urban areas where the surface temperature of the area tends to be warmer than the surrounding area. The UHI distribution was obtained from the results of further processing of the surface temperature or LST of Depok City, using the equation used by Jatmiko (2015), namely Tmean – (μ + 0.5 α). The UHI values for Depok City are shown in Table 3 below.*

Table 3. UHI Value for Depok City in 2011 and 2021.

Year	Threshold ValueUHI (℃)	Maximum UHI Value (℃)	Standard Deviation
2011	25,1	7,18	1,36
2021	29,16	4,22	1,33

Source: Data processing, 2022.

The UHI value of Depok City in 2011 and 2021 as contained in Table 3 above, it is known that in 2011 Depok City had a standard deviation of surface temperature 1.36 with a UHI threshold value of 25.1℃ and a maximum UHI value of 7.18℃. While in 2021 it has a standard deviation of 1.33 with a UHI threshold value of 29.6℃ and a maximum UHI value of 4.22℃. . The difference in the UHI threshold value and the standard deviation results in a different UHI value in each year. The difference in UHI temperature variation is caused by the large or small difference between the UHI threshold value and the maximum surface temperature, the greater the difference in value, the greater the temperature variation of the UHI distribution. The area of Depok City UHI is shown in Figure 6 below.

Figure 6. Graph of Urban Heat Island Area of Depok City in 2011 and 2021.

Source: Data processing, 2022.

The UHI classification in Depok City in 2011 and 2021 has the same classification, namely low, medium, and high, but with different interval values for each class. In 2011 the UHI classification in Depok City was classified as low (0 – 2.4℃), medium (2.5 – 4.9℃), and high (≥5℃), while in 2021 the classification was low (0 – 1.4℃), medium (1.5 – 2.9℃), and high (≥3℃). In 2011 it had a total area of 52.09 Km2, consisting of a low-grade UHI distribution of 49.64 Km2, a medium class 2.41 Km2, and a high class 0.031 Km2. In 2021, the distribution of UHI in Depok City will be 65.63 Km2, consisting of a low-grade UHI covering an area of 55.22 Km2, a medium class area of 10.07 Km2, and a high-class 0.338 Km2. Broadly speaking, in 2021 there will be an increase in the area of the UHI phenomenon of 13.54 Km2. To find out the composition of the surface temperature of each UHI class in 2011 and 2021, it can be seen in Figure 4 above, while to analyze the area and distribution of UHI in Depok City, it can be seen in Figure 6 and Figure 7 below.

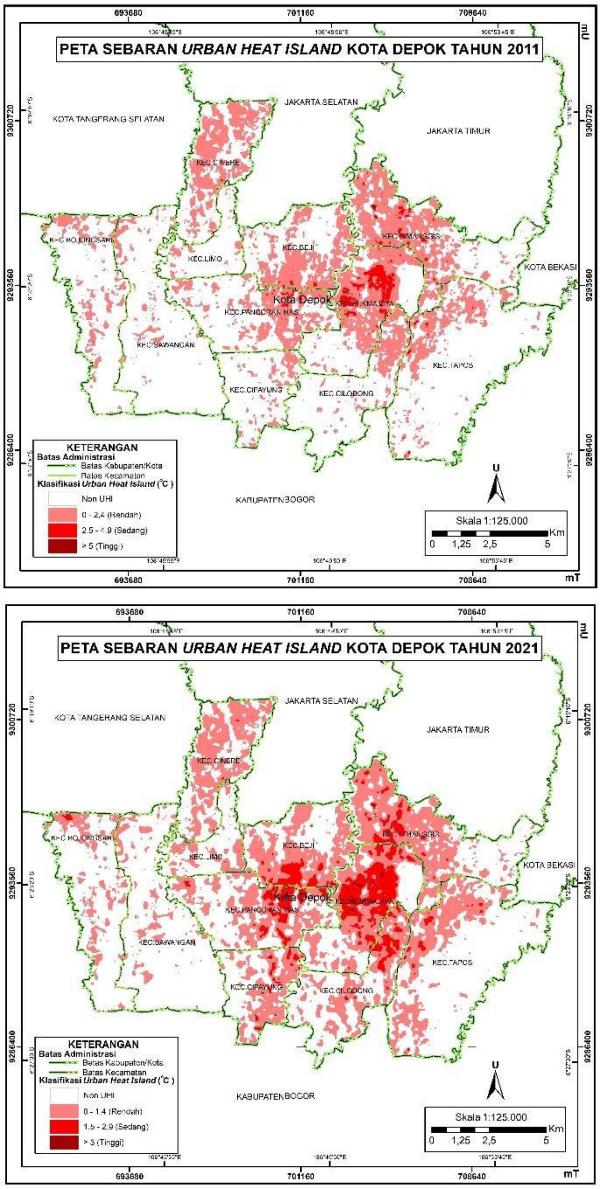

Figure 7. Urban Heat Island Distribution Map for Depok City in 2011 and 2021.
Source: Data processing, 2022.

Based on the UHI distribution map for Depok City in 2011 and 2021 contained in Figure 7, it is known that in 2011 the UHI phenomenon had a dominant distribution in the central and northern parts of the Depok City area, which is directly adjacent to big cities such as East Jakarta City, Jakarta City South, and South Tangerang City, while in 2021 there will be an expansion of the dominant distribution of the UHI phenomenon, reaching the southern part of Depok City which borders Bogor Regency. The distribution of low-grade UHI in 2011 has an area of 49.64 Km2, in this class is an area with a small surface temperature distribution of class II (22.6 – 25.1) and dominated by surface temperature class III (25.2 – 27, 7℃), the distribution of low-class UHI in 2011 was dominant in sub-districts in the central and northern part of Depok City such as in Cimanggis District with an area of 9,805 Km2, Sukmajaya District with an area of 7,007 Km2, Cinere District with an area of 6.769 Km2, Beji District with an area of 6,001 Km2, Pancoran Mas District with an area of 5,682 Km2.

In 2021 the low-class level was expanded to 55.22 Km2. The distribution of low-grade UHI in 2021 is an area where the distribution of surface temperature is dominated by surface temperature class IV (27.8 – 30.3℃). In 2021, low-class UHI will be dominant in the northern and southern parts of Depok City. The central and northern parts are dominated by similar sub-districts in 2011, but with a decreasing area in each sub-district, with the exception of Beji District which experienced an increase in area to 6,014 Km2 and Pancoran Mas District which experienced an increase in area to 6.3 Km2 , penetrated to the south with a dominant distribution in Cipayung District with an area of 4.564 Km2 and Cilodong District with an area of 5.319 Km2. In terms of the composition of the surface temperature of the low class UHI classification level in 2011 and 2021, there will be an increase in the average surface temperature at the low UHI classification level in 2021. The distribution of UHI with a low classification level has a distribution in all sub-districts in Depok City each year.

The distribution of medium class UHI in 2011 has an area of 2.41 km2, which in areas with this class distribution is dominated by class IV surface temperatures (27.8 – 30.3℃). The distribution of medium-class UHI in 2011 was distributed in almost all sub-districts in Depok City except for Bojongsari District, Cipayung District, and Limo District, with a dominant distribution in the central part of Depok City, namely in Sukmajaya District with an area of 1.665 Km2, and the northern part the area of Depok City, namely Cimanggis District with an area of 0.401 Km2. In 2021 the moderate class UHI has an area of 10.07 km2, the distribution of this class UHI is an area with a partial distribution of class IV surface temperatures (27.8 – 30.3 ℃) and more dominant class V surface temperatures (≥30.4 ℃) . The distribution of medium class UHI has distribution throughout the sub-districts in Depok City, the dominant distribution is in the central and northern parts of Depok City such as Sukmajaya District with an area of 4,233 Km2, Pancoran Mas District with an area of 1,606 Km2, Beji District with an area of 1,293 Km2, Cimanggis District with an area of 1.098, and Cilodong District with an area of 0.983 Km2, the sub-district areas in 2011 where there was no moderate distribution of UHI, but in 2021 there will be a moderate distribution of UHI such as in Bojongsari District with an area of 0.077 Km2, Cipayung District with an area of 0.437 Km2, and Limo District with an area of 0.005 Km2.

The distribution of high class UHI is the class that has the smallest distribution compared to other classes in each year. The distribution of UHI with high class levels in 2011 has an area of 0.031 Km2, with distribution only in Cimanggis District with an area of 0.027 Km2 and Tapos District with an area of 0.004 Km2. The distribution of UHU classified as high class (≥3℃) in 2021 has an area of 0.338. The distribution of this UHI phenomenon in 2021 is in the Sukmajaya District with an area of 0.263 Km2 and the Pancoran Mas District with an area of 0.073 Km2. UHI distribution with class levels in 2011 and 2021 is an area with class V surface temperature distribution (≥30.4℃) in each year.

The increase in the surface temperature of Depok City in the 2011 and 2021 time periods was accompanied by an increase in the area of the UHI phenomenon, this was indicated by the average surface temperature in each UHI class which increased in that time period and an increase in the area of the UHI phenomenon. The UHI threshold value in 2011 was 25.1℃, while in 2021 it will be 29.16℃. The UHI threshold value for Depok City in 2021 is higher than in 2011, but the area of the sub-district in Depok City has a surface temperature that is higher than the UHI threshold value or indicates an UHI phenomenon is wider than in 2011, so that the area the UHI phenomenon in 2021 is wider than in 2011. Even though it has a wider distribution of UHI in 2021, the standard deviation value of LST or the value of the proximity of surface temperature to the average temperature is smaller, namely 1.33 compared to 2011 which has a standard deviation value of 1.36, resulting in smaller surface temperature variations in 2021 compared to 2011. The maximum UHI temperature value in 2011 was 7.18 ℃ while in 2021 it was 4.22 ℃. The value of the variation in UHI temperature is influenced by the threshold value and maximum surface temperature each year, the greater the difference in the threshold value and maximum surface temperature, the greater the variation in UHI temperature.

Broadly speaking, the increase in the area of the UHI phenomenon in Depok City in the period 2011 and 2021 is 13.54 Km2, the area consists of 3 classes of classification of UHI phenomena. The distribution of the low-class UHI phenomenon is the dominant class in 2011 and 2021, there is an increase in area of 7.66 Km2, in the medium class it increases by 5.58 Km2, and in the high class it increases by 0.307 Km2. An increase in the broad distribution area of UHI also occurred in a study conducted by Fajrin & Driptufany (2019), the results of which In 2007 the distribution of UHI was in the northern part of the city of Padang by 31.37 Ha, in 2013 it increased to an area of 4,261.46 Ha, which was dominant in the northern part of Padang. the western region of the city of Padang, in 2017 the distribution of UHI experienced a significant increase, having a distribution throughout the suburbs with an area of 8,754.60 Ha. Visually, the UHI phenomenon in Depok City in 2011 and 2021 was reviewed based on the distribution of classification levels centered on the central part of the Depok City area, namely in Pancoran Mas District in 2011, reaching Sukmajaya District in 2021. The land cover built in Depok City in 2011 had an average – the average surface temperature is 25.1℃ while in 2021 it has an average surface temperature of 29.8℃, this surface temperature is the same or higher than the UHI threshold value in each year, so it is indicated that areas where land cover is distributed awakened mostly indicated UHI occurred.

4. Conclusion

The distribution of land cover in Depok City in 2011 and 2021 has changed in area. The distribution of built-up land cover has developed significantly, in 2011 it has a dominant distribution in the central and northern parts of Depok City, encroaching on the southern part in 2021. The development of built-up land cover area has resulted in a decrease in the area of other land covers, especially vegetation land cover, in 2011 and 2021 vegetation land cover has a dominant distribution in the western, eastern and southern parts of the Depok City area. There has been a change in the dominance of the distribution of surface temperature classes, in 2011 it was dominated by surface temperature class II with a dominant distribution in the western, eastern and southern parts of the Depok City area, while in 2021 it was dominated by the distribution of class IV surface temperatures with a distribution almost dominating the entire area of Depok City , more dominant in the northern, central and southern parts of the Depok City area. The effect of the development of built-up land cover on the increase in surface temperature of the City of Depok has a strong relationship with an R value of 0.636 and a coefficient of determination of 0.405, the development of the area of built-up land cover has an influence on an increase in the surface temperature of Depok City by 40.5%. The increase in average surface temperature is directly proportional to the increase in the value of the UHI threshold for Depok City in the 2011 and 2021 time periods. The distribution of UHI in 2021 has a threshold value and area that is greater than in 2011, due to the area of Depok City which has a temperature The surface area is higher than the UHI threshold value which is wider than in 2011, so that the UHI distribution in Depok City will experience an increase in area in 2021. distribution of UHI penetrated in the South.

Research suggestions related to surface temperature and UHI are using the same Landsat imagery so that the results are more accurate, as well as adding other parameters related to surface temperature. The development of built-up land has an effect on increasing the temperature of Depok City, so it is suggested that the government control the development of built-up land. The central part of the Depok City area is the center of the distribution of high class surface temperature and UHI so it is necessary to hold heat-absorbing land cover such as vegetation. For the community to be wise in managing the land they own or in the sense of being wise in carrying out developments in order to minimize the increase in the surface temperature of the City of Depok.

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