

Spatial Modelling of Air Surface Temperature Due to Land Cover Change at Caturtunggal Village, and Sinduadi Village

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Abstract: The rapid development of urban areas has played a role in increasing the symptoms of urban heat islands (UHI). There is a strong physical relationship between air surface temperature (air surface temperature, or AST) and land surface temperature (LST). Remote sensing technology can already be utilized to obtain an overview of land cover based on the values of vegetation density and building density. Gadjah Mada University (UGM) was chosen because it has planned to build green open spaces in the surrounding villages since 2014. Spatial analysis methods are used to determine patterns of land cover change, land surface temperature, and air surface temperature models. Statistical analysis was carried out to see the relationship between the land cover model and air surface temperature. Land cover in and around the UGM campus area from 2013, 2017, and 2021 continues to change. The pattern of changes in land surface temperature follows changes in land cover that occur in the study area. The increase in land surface temperature is proportional to the increase in built-up area. The greatest increase in land surface temperature tends to occur in areas showing a change from vegetated to built-up land cover. The highest air surface temperature was 30.37 °C in the built-up land cover class, while the lowest air surface temperature was 28.91 °C in the agricultural vegetation land cover class. An increase in air surface temperature of more than 1°C is caused by changes in land cover from vegetation to built-up areas. Air surface temperature is closely related to land cover. The more developed the land cover, the higher the air surface temperature.

Keywords: Land Cover, Land Surface Temperature, Gadjah Mada University, M-AST.

Introduction

Land cover change is one of the most easily observable consequences of changing an ecosystem and has a significant impact on the local, regional, and global environment (Xiao et al., 2007). The rapid development of urban areas has played a role in increasing the symptoms of urban heat islands (UHI; Wibowo et al., 2020). UHI is a unique phenomenon of urban ecosystems that is caused by a mixture of physical environmental conditions and human activities. Human activities release anthropogenic heat, which is harmful to the environment, especially the air (Indrawati et al., 2016), and can affect an increase in global climate temperatures. (Wang et al., 2019).

Air surface temperature (air surface temperature, AST) and land surface temperature

(LST) have a strong physical relationship (Benali et al., 2012). AST is the state of hot and cold air in the surface circulation system, which is the result of the interaction of the atmosphere with the land and the flow of energy between the two (Benali et al., 2012). Meanwhile, LST is the state of temperature in all fields and objects on the earth's surface and includes all urban features such as roads, roofs, walls, and even trees (Shi and Zhang, 2018). This condition can be described by differences in temperature in urban areas, which are often warmer when compared to rural areas; this phenomenon is influenced by the lack of vegetation cover in urban areas and the high area of built-up land (Alexander, 2020). Currently, remote sensing technology can be utilized to obtain an overview of land cover based on vegetation density and building density values (Jang et al.,

2020). The higher the value of the vegetation density, the lower the LST, and the higher the building density value, the higher the LST (Madaarah et al., 2019). As a result, remote sensing is considered effective in analyzing the relationship between land cover and LST in practice (Wibowo & Salleh, 2018).

Land cover change is the result of two aspects, namely human activities and natural variations of the earth system (Dong et al., 2013). In this study, the campus area was chosen because the variation in land cover is similar to that in urban areas. The land cover in and around the campus has something in common, namely being covered with vegetation, water bodies, and built-up land. Campuses are also considered urban areas on a smaller scale because of their size, population, and various activities that take place there (Alshuwaikhat & Abubakar, 2008). Activities in the campus area can dynamically change the shape of land cover in the campus area and affect LST (Madakarah et al., 2019). Thus, this research is expected to provide an overview of the relationship between land cover change and LST.

Gadjah Mada University (UGM) was chosen because it has planned to build green open spaces (RTH) in the surrounding villages since 2014 (UGM, 2014). The program is named Kampung Hijau; this program aims to build values of natural preservation and a spirit of caring for the environment in the community (Suratman, 2014). UGM and the community around the campus have great potential to become examples of "green villages" in empowering and developing sustainable urban communities (Dewi, 2021). The interaction between students and the community can indirectly form a society with an urban character (UGM, 2014). The presence of UGM students creates a new source of economic growth for the community surrounding the campus (Dewi, 2021). Student needs for housing, food, and other needs are an opportunity for the community around the campus as a source of their income (Suratman, 2014).

Materials and Methods

Study Area

The research area is divided into two villages, namely Sinduadi Village and Caturtunggal Village. Sinduadi Village is in the Mlati District, while Caturtunggal Village is in the Depok District. The two villages have one thing in common: they are both in Sleman Regency, DIY. The study area is geographically located between $7^{\circ}44'35.70''$ and $7^{\circ}47'29.60''$ South and $110^{\circ}21'0.50''$ and $110^{\circ}25'14.00''$ East. **Figure 1.1** depicts the administrative areas of Caturtunggal Village and Sinduadi Village.

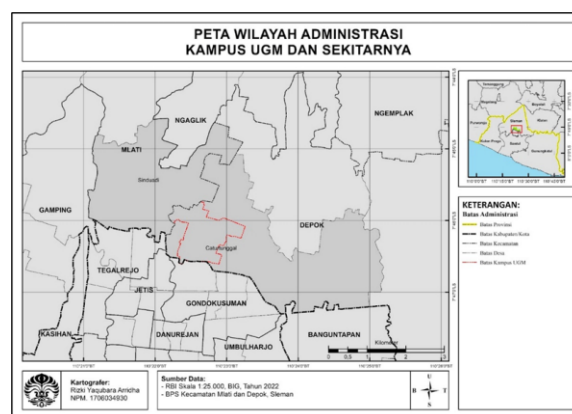


Figure 1.1 Administrative areas of Caturtunggal Village, and Sinduadi Village

The study area has an area of 1757.7 hectares, with the distribution of areas per village shown in **Table 1.1**. Based on data acquisition, it appears that the largest village area is Caturtunggal Village, while the smallest village area is Sinduadi Village.

Tabel 4.1 Areas of Village

No.	Village	Areas (Ha)	Areas (%)
1.	Caturtunggal	1088,6	61,9
2.	Sinduadi	669,1	38,1
	Total	1757,7	100

Procedures

Flow of Research Thinking

This study uses three main variables, namely land cover, land surface temperature, and air surface temperature. Changes in land cover and land

surface temperature will be observed in 2013, 2017, and 2021 through image analysis. In addition, the variable land surface temperature and air surface temperature will be processed to build a air surface temperature model (M-AST). The results of the M-AST processing were then identified in terms of land cover, which was then converted into a spatial model of air surface temperature. The flow of research thinking can be seen in **Figure 1.2**.

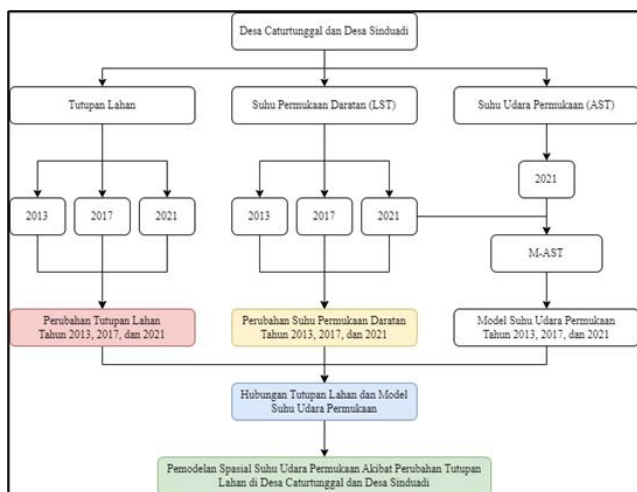


Figure 1.2 Flow of Research Thinking

Data Processing

The processed data is spatial data from Landsat 8 OLI/TIRS satellite imagery obtained in the month with the lowest rainfall with no more than 10% cloud cover. Landsat image processing is done on Google Earth Engine, so no pre-processing is done because the image has been corrected geometrically, radiometrically, and atmospherically. The next step is to crop the image according to the research area using the "Extract by Mask" method. This is intended so that the processed data will focus on the study area. The research area, which includes two villages, Sinduadi Village and Caturtunggal Village, is cut using the research area.

Then data processing is carried out based on three variables: first processing to find the estimated value of land surface temperature (LST), then regression from the LST results with field survey results (AST or air temperature), and third processing land cover change data in 2013, 2017, and 2021 to identify the trend of change.

Data Analysis

The analysis used in this study uses spatial analysis to determine patterns of change in land cover, land surface temperature, and air surface temperature models. Then a temporal analysis was carried out to compare the distribution in 2013, 2017, and 2021. This is due to the diversity of different weather conditions in different years. In this analysis, the results of image processing and field investigations are discussed by grouping data into tables, graphs, and/or images. A comparative analysis of visual maps was also carried out to identify changes in land cover and area each year. To see the relationship between the land cover model and air surface temperature, statistical analysis was carried out using the correlation of the two variables using the correlation test. In addition, a descriptive analysis was carried out to describe the relationship between land cover models and air surface temperature, which will be carried out in 2013, 2017, and 2021 for the spatial modelling of air surface temperature in Caturtunggal Village and Sinduadi Village.

Results and Discussion

Result 1 – Land Cover in Caturtunggal Village and Sinduadi Village

Each class of land cover in Caturtunggal Village and Sinduadi Village has been changing since 2013, 2017, and 2021. Land cover in 2013 was dominated by built-up land with a total of 1202 grids, or around 1202 hectares. Over a period of eight years (2013–2021), the area of built-up land has increased by 6.35% (116 hectares) from 1202 grids (1202 hectares) to 1318 grids (1318 hectares). In addition to built-up land, the area of non-agricultural vegetation and agricultural vegetation is also quite extensive. However, changes in land cover area occur on an annual basis.

In 2013–2021, the area of non-agricultural vegetation decreased by 8.15% (149 hectares) from 311 grids (311 hectares) to 162 grids (162 hectares). In addition, agricultural vegetation experienced an increase in area of 1.64% (30 hectares) from 313 grids (313 hectares) to 343 grids (343 hectares). The decrease in the area of non-agricultural vegetation

was followed by a significant increase in the area of built-up land. In 2021, as shown in **Figure 2.1**, changes in spatial land cover are occurring quite rapidly in the study area, which is dominated by changes from non-agricultural vegetation to agricultural vegetation and agricultural vegetation to built-up land.

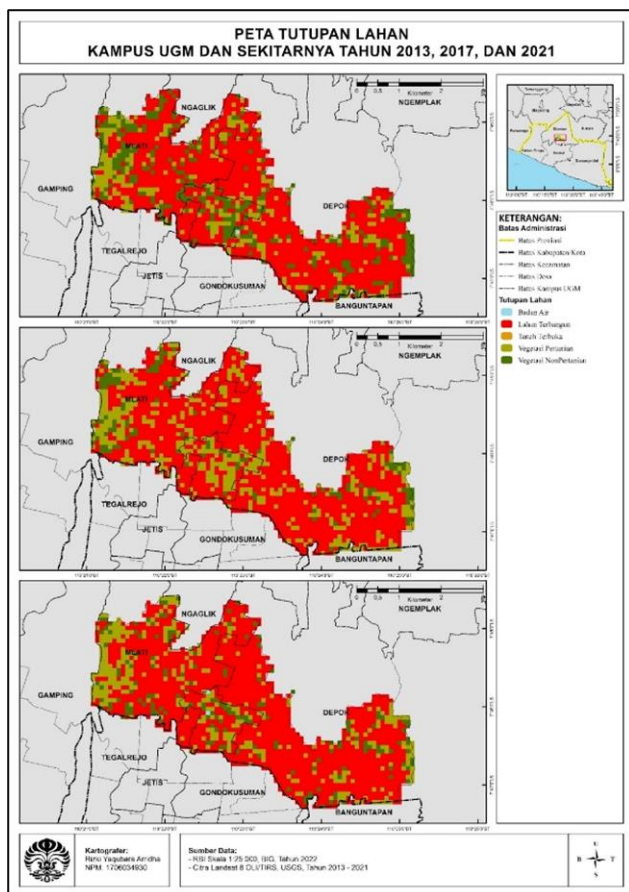


Figure 2.1 Map of Land Cover in Caturtunggal Village and Sinduadi Village in 2013, 2017, and 2021

Changes in land cover that occurred in 2013–2017 occurred in 280 grids. Changes in land cover that occur are bodies of water into built-up land, built-up land into open land, built-up land into agricultural vegetation, non-agricultural vegetation into built-up land, non-agricultural vegetation into open land, agricultural vegetation into built-up land, and agricultural vegetation into non-agricultural vegetation. In 2013–2017, there were many changes in land cover that led to the development of built-up areas, especially in the central part of the research area. This is because this section is the main access road to the UGM

campus area from the Yogyakarta City area, which has led to an increase in the construction of supporting facilities such as housing, supermarkets, and restaurants. Changes in land cover toward agricultural vegetation occurred mainly within the UGM campus. Changes in the land cover of Caturtunggal Village and Sinduadi Village in 2013–2017 are shown in **Figure 2.2**.

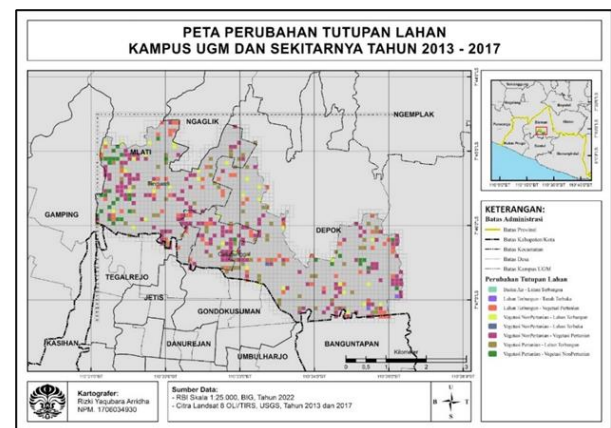


Figure 2.2 Map of Land Cover Changes at Caturtunggal Village and Sinduadi Village in 2013 – 2017

In 2017–2021, there were 325 grids that experienced changes in land cover. Built-up land becomes water bodies; built-up land becomes open land; built-up land becomes non-agricultural vegetation; built-up land becomes agricultural vegetation; open land becomes built-up land; non-agricultural vegetation becomes agricultural vegetation; agricultural vegetation becomes non-agricultural vegetation. Built-up land experiences the most frequent changes in land cover. This change is evenly distributed in all research areas, including the UGM campus area. Changes in land cover during the 2017–2021 period are shown in **Figure 2.3**. The pattern of land cover change in Caturtunggal Village and Sinduadi Village is in accordance with the existing development pattern. The type of land cover that has experienced a large increase in area is built-up land. This is inversely proportional to the area of land cover for non-agricultural vegetation, which continues to decrease. Developments in Caturtunggal Village and Sinduadi Village took place quite quickly on slopes of 0-8%. This is because the area is sloping, so development is easier to do.

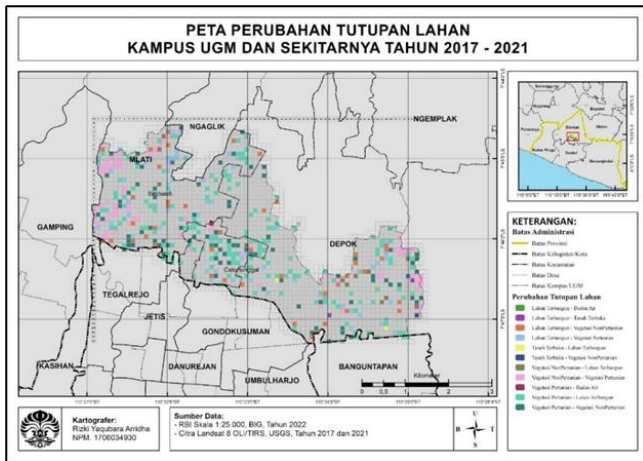


Figure 2.3 Map of Land Cover Changes at Caturtunggal Village and Sinduadi Village in 2017 – 2021

The main reason for the change in land cover is the ongoing development in Caturtunggal Village and Sinduadi Village. construction of student facilities and infrastructure on campus, student residences around campus, and other student support facilities The existence of the campus causes changes in land use around it to meet the needs of students. settlements, restaurants, and other supporting places such as mini markets, photocopying, internet cafes, and laundry (Kolawole & Boluwatife, 2016). Another factor is population growth, which increased from 2013 to 2021 to more than 86,000 people in Caturtunggal Village and Sinduadi Village.

Result 2 – Land Surface Temperature in Caturtunggal Village and Sinduadi Village

Changes in land cover that occur every year are one of the causes of changes in land surface temperature. In general, land surface temperatures in Caturtunggal and Sinduadi Villages have increased from 2013 to 2021. The rise in temperature is usually due to the addition of buildings in Caturtunggal Village and Sinduadi Village. Developments that are increasing, such as settlements, parks, and other supporting facilities, generally change vegetated land into built-up land. As a result, the land surface temperature in Caturtunggal and Sinduadi Villages continues to rise year after year as the built area grows and the vegetation area shrinks. Changes in land surface temperature in Caturtunggal Village and Sinduadi

Village in 2013, 2017, and 2021 are shown in Figure 2.4.

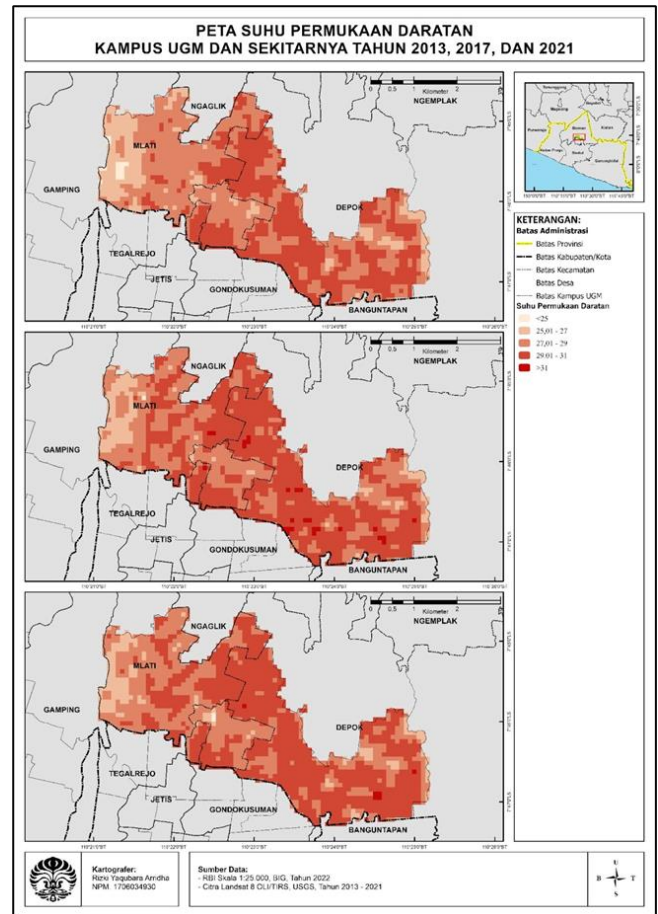


Figure 2.4 Map of LST in Caturtunggal Village and Sinduadi Village in 2013, 2017, and 2021

Land surface temperatures in 2013–2017 generally tended to be constant and increased in some areas. The land surface temperature that does not change is 1275 grid cells or around 70.64% (1275 hectares). The increase in land surface temperature is 497 grids, or about 27.53% (497 hectares). Meanwhile, the land surface temperature that has decreased is only 33 grids, or around 1.83% (33 hectares). The land surface temperature seems to change more in the western part of the study area. If you look at the land cover class, the land surface temperature that has increased is included in the class of non-agricultural vegetation land cover and agricultural vegetation. Meanwhile, land surface temperatures that tend to be stable are included in the built-up land cover class. The increase in land surface temperature in the study area was caused by changes in land cover,

especially from non-agricultural vegetation to agricultural vegetation and built-up land. Changes in land surface temperature in 2013–2017 are shown in **Figure 2.5**.

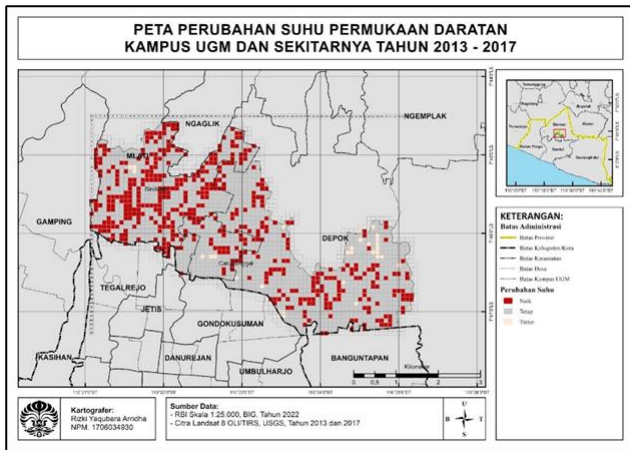


Figure 2.5 Map of Land Cover Changes at Caturtunggal Village and Sinduadi Village in 2013 – 2017

The land surface temperature in Caturtunggal Village and Sinduadi Village is generally stable and has slightly increased from 2017 to 2021. The increase in land surface temperature is 122 grids covering 6.76% (122 hectares). The land surface temperature that has not changed is 1520 grids, or around 84.21% (1520 hectares), and the land surface temperature that has decreased is 163 grids, or around 9.03% (163 hectares). The increase in land surface temperature spread evenly across almost all study areas. This is consistent with changes in land cover that occur, especially changes from vegetated land cover to built-up land cover. Changes in land surface temperature during the 2017–2021 period are shown in **Figure 2.6**.

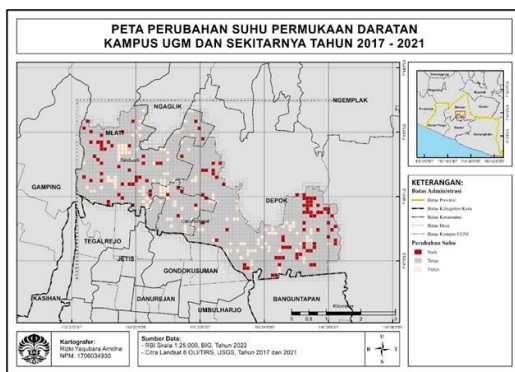


Figure 2.6 Map of Land Cover Changes at Caturtunggal Village and Sinduadi Village in 2017 - 2021

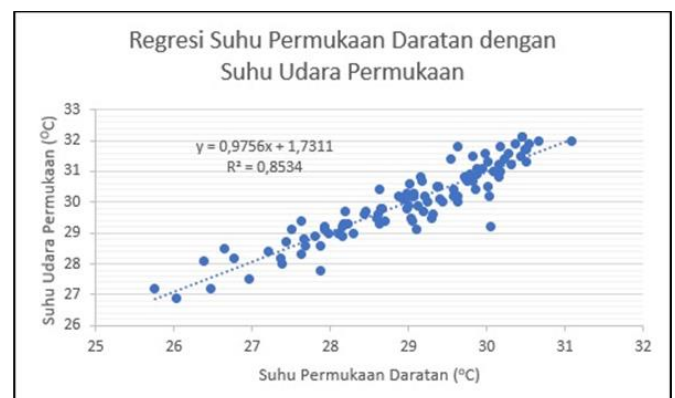
The pattern of changes in land surface temperature follows changes in land cover that occur in and around the UGM campus area. Changes in land cover will affect land surface temperatures spatially and temporally (Shidiq et al., 2020). The land surface temperature in and around Caturtunggal Village and Sinduadi Village continues to increase every year. An increase in land surface temperature is consistent with a large increase in built-up land cover. The greatest increase in land surface temperature tends to occur in areas that show a transition from vegetation to built-up areas (Madakara et al., 2019).

Result 3 – Air Surface Temperature Modelling

The air surface temperature model can be obtained by a simple linear regression procedure by regressing the land surface temperature values processed using satellite imagery with air surface temperature values obtained in the field. Land surface temperature was obtained from Thermal Band processing of Landsat 8 satellite imagery, while air surface temperature was obtained from field surveys measuring temperature at 100 sample points divided by land cover class in Caturtunggal Village and Sinduadi Village.

In the regression equation between land surface temperature values and air surface temperature values, the AST (M-AST) model equation is obtained, namely $y = 0.9756x + 1.7311$ with a coefficient of determination (R^2) of 0.8534. The regression of air surface temperature with land surface temperature is shown in **Figure 2.7**.

Figure 2.7 Regression of Land Surface Temperature and Air Surface Temperature



Source: Research Data Processing (2022)

Based on the regression results (Figure 5.14), it is known that land surface temperature can explain 85% ($R^2 = 0.8534$) of the air surface temperature model. In Caturtunggal Village and Sinduadi Village, there were linear positive results between land surface temperature values and air surface temperature models. The AST model (M-AST) can thus be described by the following equation:

$$M-AST = 0,9756 (LST) + 1,7311$$

With the existing equations, air surface temperature modelling was carried out in Caturtunggal Village and Sinduadi Village. Air surface temperature modelling based on land cover classes was carried out in Caturtunggal Village and Sinduadi Village in 2013, 2017, and 2021.

The RMSE test was carried out on the 2021 air surface temperature model to determine the level of accuracy and correctness of air surface temperature modelling based on air surface temperature data from field measurements. The RMSE test results give an RMSE value of 0.464, which means there is an error of 0.464 in the air surface temperature model data. This means that the value of the largest deviation from the model value of air surface temperature to the air surface temperature in the field is 0.464.

Based on the results of air surface temperature modelling for 2013, 2017, and 2021, Caturtunggal Village and Sinduadi Village are classified into five temperature classes, namely: 25.5-27°C; 27.01-28.5°C; 28.51-30°C; 30.01-31.5°C; and >31.5°C. Air surface temperature models in Caturtunggal Village and Sinduadi Village in 2013, 2017, and 2021 are shown in Figures 2.8, 2.9, and 2.10.

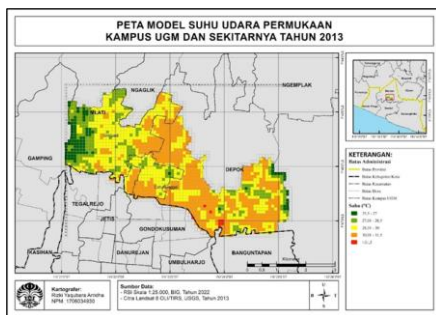


Figure 2.8 Map of MAST in Caturtunggal Village and Sinduadi Village in 2013

In 2013, the temperature value was dominated by a temperature class of 28.51-30°C with a total of 737 grids, or around 40.45% (737 hectares), and a temperature class of 30.0-31.5°C with a total of 718 grids, or around 39.41% (718 hectares). The temperature value with the smallest area is the temperature class >31.5 °C, with a total of 8 grids and a proportion of 0.44% (8 hectares). Temperature classes of 28.51-30°C and 30.0-31.5°C are spread throughout almost the entire study area, except for the western part. In terms of land cover, the temperature classes of 28.51-30°C and 30.0-31.5°C are dominated by built-up land cover. While the temperature class >31.5 °C is only found in a few places in the southeastern corner of the study area, specifically in the built-up land cover class.

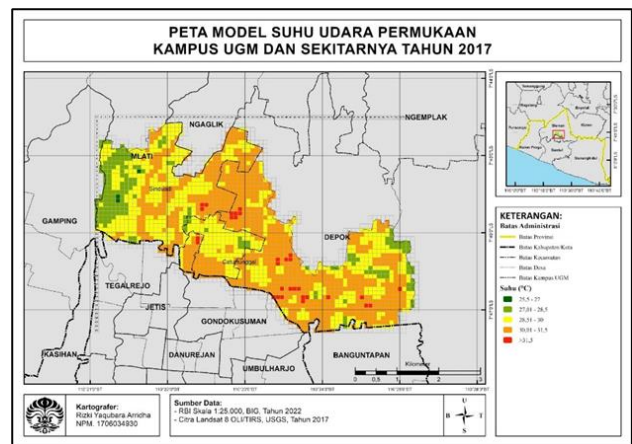


Figure 2.9 Map of MAST in Caturtunggal Village and Sinduadi Village in 2017

In 2017, the temperature value was dominated by the temperature range of 30.0-31.5 °C, with a total of 911 grids, or around 50% (911 hectares). The temperature value with the smallest area is the temperature class of 25.5-27 °C, with a total of 3 grids and a proportion of 0.16% (3 hectares). The temperature class of 30.0-31.5°C is spread throughout almost the entire study area, except for the extreme west, east, and center. In terms of land cover, the temperature range of 30.0-31.5 °C is dominated by built-up land cover. While the temperature class of 25.5-27°C is only found in a few places in the western part of the study area, to be precise, in the land cover classes of agricultural vegetation and non-agricultural vegetation

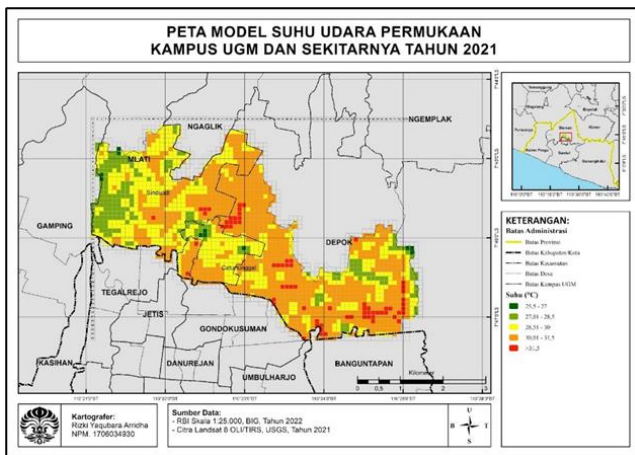


Figure 2.10 Map of MAST in Caturtunggal Village and Sinduadi Village in 2021

In 2021, the temperature value is dominated by the temperature class of 30.0–31.5 °C with a total of 924 grids, or around 50.71% (924 hectares). The temperature value with the smallest area is the temperature class of 25.5–27 °C, with a total of 11 grids and a proportion of 0.6% (11 hectares). The temperature class of 30.0–31.5 °C is spread out in the northern, eastern, and southern parts of the study area, and only a small part is in the western part. In terms of land cover, the temperature range of 30.0–31.5 °C is dominated by built-up land cover. While the temperature class of 25.5–27°C is found in several places at the western end, eastern end, and centre of the study area, to be precise, in the agricultural vegetation land cover class and a little in the non-agricultural vegetation class.

Air surface temperature is affected by differences in elevation and slope within each land cover. At lower altitudes, the air surface temperature is also lower. Meanwhile, the slope level affects the types of plants in the vegetation land cover class. In addition to elevation and slope, land cover heterogeneity also greatly affects temperature values.

Result 4 - Relationship of Land Cover and Air Surface Temperature Models

The relationship between the land cover model and air surface temperature (M-AST) can be analyzed using the Rank-Spearman correlation test. This is because the Spearman's rank correlation test is part

of nonparametric statistics. To perform the Spearman's rank correlation test, the land cover and M-AST data were ranked by high and low temperatures.

The ranking of land cover data and M-AST is subdivided based on the number of classes in each data set. Ground cover is divided into five ranks, and M-AST is divided into five ranks. To determine whether there is a relationship between land cover and M-AST, the magnitude of the resulting correlation is interpreted using a correlation coefficient interpretation table.

Based on the results of the land cover correlation test and M-AST in Caturtunggal Village and Sinduadi Village in 2013, 2017, and 2021, a significance value, or Sig, was obtained. (2-tailed) in three years is 0.000. Because the value of sig. (2-tailed) 0.000 is less than 0.05, there is a significant relationship between the land cover variable and M-AST. From the SPSS output, the correlation coefficient is 0.602**, 0.608**, and 0.604*, which means the strength of the relationship between the land cover variable and M-AST is 0.6 or meets the strong correlation coefficient interpretation guidelines. The correlation coefficient is positive, so the relationship between the two variables is unidirectional, meaning that the more land cover that is built up, the higher the air surface temperature.

Discussion

Based on the results of data processing, which can be presented in the form of a land cover map, it can be seen that the land cover area is built up with high land surface temperatures. In contrast to areas with low land surface temperatures, there are non-agricultural land-cover areas. Another land cover that also has a high average temperature value is open land. This is consistent with the theory that materials such as metal, stone, and asphalt that make up built-up and open land materials have a higher heat capacity and heat input than vegetated land materials.

Each object has a different ability to receive and radiate the solar energy it receives. The surface structure of built-up land, which is generally impermeable, causes objects to absorb and release energy more quickly. This means that the energy

radiated from built-up areas tends to be larger and is then recorded by satellite sensors. This is different from what happens on vegetated land, where vegetation can absorb solar energy for the photosynthesis process, which is then released in the evapotranspiration process. This process has a cooling effect, so that the temperature that will be emitted is lower than the temperature that is received, so that the temperature that is emitted is recorded by the satellite sensor.

Conclusions

Land cover in and around the UGM campus area from 2013, 2017, and 2021 continues to change. The pattern of land cover change in Caturtunggal Village and Sinduadi Village is in accordance with the existing development pattern. The type of land cover that has experienced a large increase in area is built-up land. This is inversely proportional to the area of land cover for agricultural and non-agricultural vegetation, which continues to decrease. The main reason for the change in land cover is the construction of student support facilities, which keep popping up in and around the UGM campus area.

The land surface temperature in Caturtunggal Village and Sinduadi Village changes every year. The pattern of changes in land surface temperature follows changes in land cover that occur in and around the UGM campus area. An increase in land surface temperature is consistent with a large increase in built-up land cover. The greatest increase in land surface temperature tends to occur in areas showing a change from vegetated to built-up land cover.

Air surface temperature has a pattern caused by differences and changes in land cover in Caturtunggal Village and Sinduadi Village. The highest air surface temperature was 30.37 °C in the built-up land cover class, while the lowest air surface temperature was 28.91 °C in the agricultural vegetation land cover class. Changes in land cover from vegetation to built-up areas caused an increase in air surface temperature of up to 1.46 °C.

Air surface temperature is closely related to land cover. The more developed the land cover, the higher the air surface temperature. because the materials in buildings have a high heat capacity and a higher heat input. in contrast to areas with little development or vegetation.

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