

The Land Conversion's Characteristic and Effect to Urban Heat Island in Caturtunggal, Sleman District, Yogyakarta

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ABSTRACT

Depok Sub-District is a relatively densely populated in Sleman District, which is 5,260 people per km² with the majority of the population concentrated in Caturtunggal Village at 48.5% in 2013. Land conversion in Caturtunggal that occurred in 2000-2007 was 20.34% and continues to increase every year. The rate of population growth followed by land conversion in the form of changes in the use of open land into built-up land contributes to urban heat islands in urban areas. The land conversion from vacant land to built-up land determines the formation of urban geometry in an area through the physical elements of the city. These elements can contribute to the urban heat island. This study aims to determine the characteristics of land use change through the city's physical elements that affect Urban Heat Island in Caturtunggal, Sleman Regency, Yogyakarta. This research uses quantitative methods, namely non-experimental research and experimental research. This study is a longitudinal research using data from 2007 and 2016 periods. This research uses experimental research is a one group pre test post test design which is used to compare groups before and after being given treatment. Simulation Temperature measurement was carried out using the trial version of Envi Met 4 software. The result of the research is that for nine years from 2007 - 2016 it was 15% (26.96 Ha), the average change per year was 1.7% (3.30) and the area of land that had not been developed was 55% (106, 70 Ha), if it is not controlled and allowed to continue, it is predicted that within 32 years the land will be exhausted. The green open space area is 17%, so for the current state there may be a temperature increase exceeding 0.4-1.8°C over a period of nine years. In conclusion, four of the five characteristic variables, contribute positively to the urban heat island in Caturtunggal.

Keywords: Land conversion, City physical element, Urban heat island, Experimental research, Envimet software.

1. INTRODUCTION

The results of this research related to mapping land surface temperatures in Sleman Regency, Yogyakarta in 2013 and 2015 showed the urban heat island occurred in most areas of Depok Subdistrict [1]. Based on the results, the relatively dense population subdistrict in Sleman Regency is Depok District which is 5,260 people per km² with the majority of the population concentrated in Caturtunggal Village by 48.5% in 2013 [2]. The rate of population growth followed by the transfer of land functions in the form of changes in the use of open land into built land contributes to urban heat island in urban areas.

Caturtunggal is a village located in Depok Regency, Sleman District, Yogyakarta. Caturtunggal area of 889.748 Ha and has a settlement area of 795.7 Ha (7.957 km²) to 68% of 11.04 km² (889.748 Ha) and its density reached 7.741 people / km in 2010 [3]. Land conversion in Caturtunggal in 1993-2000 is 12.41% and in 2000-2007 by 20.34% [4]. Rapid population growth has result in increased development in various fields, which will encourage the land conversion. Base on the observed, Caturtunggal has contributed to the urban heat island effect in Sleman District, Yogyakarta.

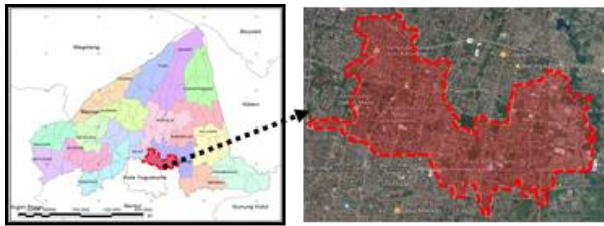


Figure 1 Location of the study area.

The land conversion's also caused by development of the city structure which are the main element as the formation of a city, in the form of urban land use [5]. Thus, Characteristic of land conversion's can be interpreted as main features of changes in land function that are able to affect the condition of urban structures in forming an urban area. That is, development without considering the sustainability of the future affects the formation of an urban geometry in the future. Urban geometry is formed due to the presence of physical elements of cities in the form of buildings and vegetation. The density of the built area, the ratio of building height, distance between buildings, the width of roads and building materials resulted in differences in air temperature in urban and sub urban areas [6].

The high land conversion causes the green open space to decrease, meaning that the more land conversion, the density in a city also increases. It is important to study the urban heat island, considering that the ever-increasing air temperature in urban areas creates an uncomfortable environment for the community. Urban heat island in urban areas can affect the environment and quality of life, increase energy consumption, air pollution emissions and the presence of greenhouse gases that can affect comfort of living in a city, and harmful to health [7]. It can be a major concern for urban planners to understand the patterns of land development and spatial distribution areas that influence the formation of urban heat islands in major cities.

2. DATA AND METHODS

2.1. Research Approach and Types of Research

The methods used is quantitative with non-experimental and experimental research. Non-experimental research aims to determine the impact, causal relationship between independent variables and determined variables where the independent variables are already available. Experimental research aims to determine the consequences of a treatment given by the researcher.

This type of research is a longitudinal study using two periods, namely 2007 and 2016. The type of experimental research selected is a one group pre test

post test design, which is used to compare groups before and after being given treatment.

2.2. Populations and Samples

This study uses a population, namely a grid unit with a size of 1 Ha (grid size based on density theory) used to determine the amount of land use change that occurs in 1 ha. The land in Caturtunggal consists of 1,318 grids, and the overlay technique is carried out using ArcGis.10 software to identify grids that have changed land use. The grids are grouped based on the percentage of land use change from 0% - 50% to determine the population to be used. The population chosen is the number of grids that experience land use change, with a range of 10.1-20% consisting of 395 grids (30% of 1,318 grids). The sample taken from a population of 395 grids is 196 grids.

3. RESULTS AND DISCUSSION

3.1. Land Conversion's Characteristic and Effect to Urban Heat Island

Total change area use in Caturtunggal for nine years from 2007 to 2016 was 16% (145.9 Ha from 889.748 Ha). The average land use change in Caturtunggal was 1.8% (16.13 Ha). It will be analyzed based on indicators of land change that contribute to urban heat island. The indicators to be identified are (a) Land Use; (b) Density of Built Area; (c) Roof Shape; (d) Roof Material (e) Building Height Ratio.

3.2. Characteristics Change Based on Land Use

Land use in Caturtunggal in 2016 was divided into two functions, namely built-up land and undeveloped land. Land use change from small buildings to large buildings by 19.12 Ha and from vacant land to built land by 10.58 Ha. The trend of land use change in Caturtunggal is from smaller buildings to larger buildings.

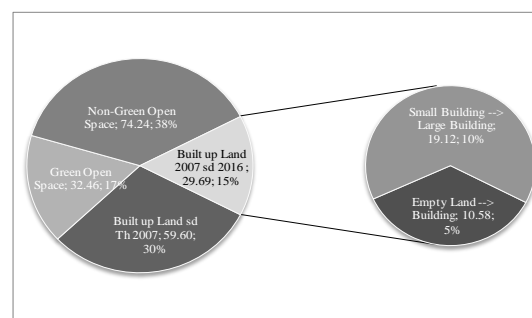


Figure 2 Land use in Caturtunggal 2016.

Land use change in Caturtunggal based on the number of samples that had been identified for nine years from 2007 - 2016 were 15% (26.96 Ha) and the average change per year was 1.7% (3.30) Ha. The area of land that has not been built is 55% (106.70 Ha) which means that if the land conversion is not controlled and allowed to continue, it can be predicted that in 32 years we will lost the land. The results of the analysis of diagram 2 is the dominant building area built in Caturtunggal is an area of <50 m², 51-100 m² and 101-200 m², so it can be interpreted that vacant land which has a minimum area of 25-200 m² has a high potential to be converted into built-up land compared to other fields.

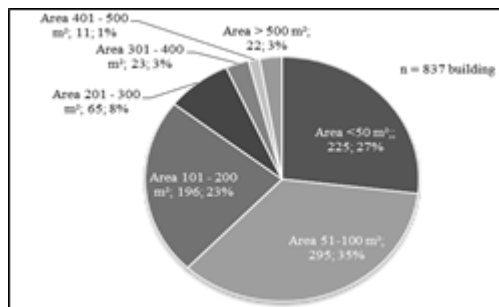


Figure 3 Characteristics of changes in vacant land in terms of building area.

The ideal green open space is 40%-50% of the size of the city. For every 50% reduction in green open space, there will be an increase in air temperature of 0.4-1.8 oC [8]. Although the addition of 50% green open space cannot directly reduce the temperature increase by 0.4-1.8 oC, the addition of green open space can reduce the air temperature by 0.2-0.5 oC. It is because the addition of green open space takes time for the process of vegetation growth.

Undeveloped land use in Caturtunggal is divided into two parts, 17% (32.46 Ha) of green open space and 38% (74.24 Ha) of green open space (Diagram 1). If the theory is applied in Caturtunggal, it is necessary to make efforts to increase green open space by 23-33% (195.4 – 293.6 Ha of the Caturtunggal land area) to meet the ideal criteria for green open space. For the current situation, it is possible for a temperature increase to exceed 0.4-1.8 oC in the Caturtunggal area for a period of nine years. Therefore, land conversion in Caturtunggal needs special attention and mitigation because it has a significant impact on increasing temperatures and contributes positively to urban heat islands.

The results of the sample, green open space in Caturtunggal is currently 17%. To meet the ideal conditions for the Caturtunggal area, it is necessary to

add 23% of green open space, so that it is not possible for horizontal land expansion, development is only possible vertically on land that has been built. Expanding or maintaining green open spaces is an important part of reducing the impact to urban heat island.

3.3. Characteristics of Change Based on the Density of Built Area

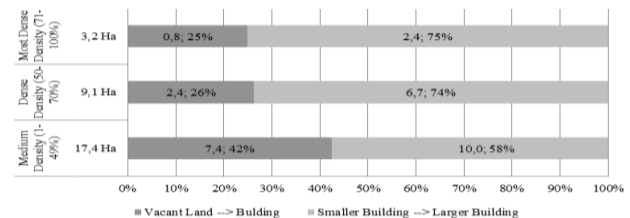


Figure 4 Land use change based on density.

The results show that the medium-density area needs special attention, because almost 50% of the land has been converted from vacant land to built-up land. This means that if the conversion of land from vacant land to buildings is still carried out continuously, then the area will turn into a high-density area. Building density will determine the surface roughness which affects albedo. The more land is built, the more radiation is reflected, so the air temperature increases. A very dense building will hinder the direction of the wind so that the wind cannot move. Wind movement is beneficial in lowering the micro temperature by spreading heat over a larger area [9].

Based on the sample, it can be concluded that almost 50% of the Caturtunggal area has a higher contribution to urban heat island. High density areas have experienced an increase in temperature so that in these areas it is necessary to plant vegetation around buildings because vegetation can reduce the reflection of light as part of the radiation spectrum, both direct rays and rays reflected by other objects around the vegetation [10].

Building on vacant land has a higher effect on the urban heat island, because land cover using materials such as concrete and cement has a high heat conductivity (three times higher than sandy soil wet). This means, if the development from vacant land to built-up land is still carried out continuously in the area, then the medium-density area has a greater risk of urban heat island occurrence and it is possible that there will be an increase in temperature higher than current conditions.

3.4. Characteristics of Changes Based on Roof Shape

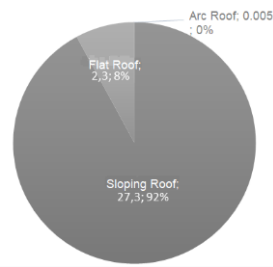


Figure 5 Characteristics of changes in roof shape in Caturtunggal.

Changes in land use based on the shape of the roof in the Caturtunggal area are dominated by changes in shape to a sloping roof (Diagram 4). 50% of the heat load on buildings comes from the roof. The roof of the building contributes 36.7% of the total solar radiation that falls on a single-story building with walls oriented towards the sun [11]. This is one of the reasons why areas with flat roofs produce more differences in the city's micro-temperature up to 1°C, so areas that use flat roofs will feel the temperature increase [12].

In Caturtunggal, roofs is dominated by sloping roofs. If it is associated with an increase in air temperature, areas that use sloping roofs contribute less to the occurrence of urban heat islands than areas that use flat roofs. Buildings with sloping roofs generate less heat than buildings with flat roofs. This means that Caturtunggal has a small contribution to urban heat islands when viewed from the change in roof shape.

3.5. Characteristics of Changes Based on Roof Material

The results of the analysis show that there are six characteristics of the use of roofing materials in Caturtunggal in 2016, namely clay tile material, aluminum tile, zinc, metal tile, transparent and concrete roof.

The criteria for using roofing materials around buildings that do not reflect heat (Heat Island Effect) is important. The benchmark is to use various materials to avoid the effect of reflecting heat on the roof area of the building so that the albedo value (solar heat reflection power) is at least 0.3 according to the calculation, as well as efforts to use a green roof of 50% of the roof area. Concrete (0.25-0.3) and clay tile (0.2) are materials with low albedo values that have great potential to absorb heat very quickly during the day, so their use needs to be controlled by reducing or limiting them [13].

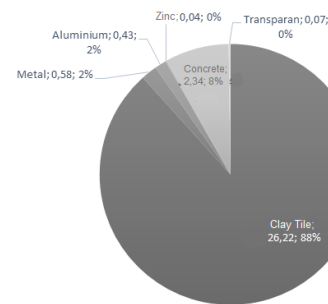


Figure 6 Characteristics of roof material changes in Caturtunggal.

The roofing material in Caturtunggal tends to lead to a sloping roof shape using clay tile material, with a percentage of 88% (26.22 Ha) and another tendency leads to the use of concrete material by 8% (2.34 Ha). The use of roofing materials such as clay tiles and concrete in excessive quantities has a negative impact on the environment because these materials receive, absorb and release the heat received, thereby increasing the air temperature. If we look at the current condition of using roofing materials in Caturtunggal, the materials used contribute positively to urban heat islands.

3.6. Characteristics of Changes Based on Building Height Ratio

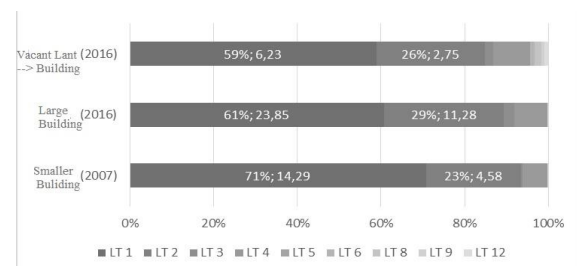


Figure 7 Changes in building height based on initial land function.

The floor changes that experienced the highest increase were one-story buildings. The tendency of land changes that occur in Caturtunggal based on the height of the building is the change from empty land to one-story buildings and changes to one-story buildings and remains one floor despite the expansion of the building. This means that development growth in Caturtunggal has developed horizontally.

Ratio contributes greatly to the occurrence of urban heat islands in urban areas. Based on that, recommends that the H/W ratio be at 0.4-0.6 to minimize trapped heat as well as other purposes, namely for solar access and minimizing the spread of air pollution [14]. The development horizontally resulted in the distance between buildings getting smaller, resulting in higher density. In high density areas (with an H/W ratio ≥ 4), it

takes longer for the surface of the material to release heat into the air so that most of the heat absorption occurs above ground level (building or roof surface). When viewed from the characteristics of the building, the ratio of building heights gives a positive contribution to the urban heat island.

4. TREATMENT

4.1. Green Roof Application on the Roof and Roof Coating Application

The area of green open space in Caturtunggal in 2016 was 17% (32.46 Ha). Based on some previous experts, the area of green open space should be 40-50% of the city area, so the Caturtunggal area needs to add about 23-33% of green open space to achieve the ideal city. One way to add green open space is the application of a green roof. Green roofs can be applied to reduce heat transmission through the roof. Green roof application will be applied to flat roofed buildings.

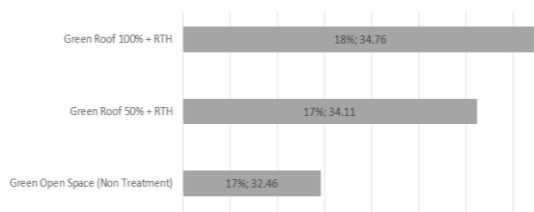


Figure 8 Green roof application simulation.

The results of the research on changes in the function of vacant land or changes in buildings from sloping roofed buildings to flat roofed buildings in Caturtunggal are 2.3 hectares for nine years. If 50% of the 2.3 Ha is made to use a green roof, then the green open space in Caturtunggal will increase to 1.65 Ha, which means that the green open space will increase but remain at 17%. If from 2.3 Ha the use of green roofs is added by 100%, then the green open space in Caturtunggal increases to 2.3 Ha, which means that the green open space increases to 18% (Diagram 7). The application of green roofs in samples of 50% or 100% on sloping roofed buildings turns out to have very minimal potential, but if it is applied in Caturtunggal in a sustainable manner in buildings that will use flat roofs, it will help expand green open space continuously and This can contribute to the extension of the life of the city of Caturtunggal.

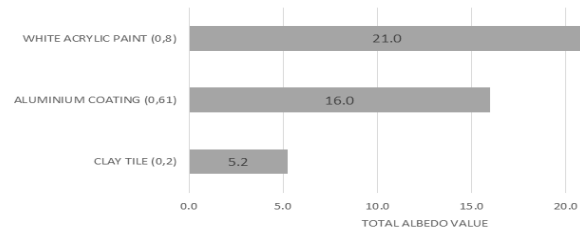


Figure 9 Treatment simulation diagram on roof material.

The characteristics of the roofing material in Caturtunggal tend to be clay tile material, which means that the material contributes greatly to temperature changes. The latent hazard that causes the urban heat island is caused by the flat roof that uses clay tiles and this material is the choice of the people who are more dominantly used in Caturtunggal but in reality it is not good for the environment.

The building which using clay tile roofing material in Caturtunggal is 26.22 Ha with an albedo value of 0.2 clay tile material, so the total area of the albedo value is 5.2. If treatment is carried out using aluminum coating with an albedo value of 0.61, the albedo area becomes 16.0 (3 times larger than clay tile) and if treated using white acrylic paint with an albedo value of 0.8, the albedo area becomes 21.0 4 (4 times larger than clay tile).

5. SIMULATION USING ENVIMET SOFTWARE

Temperature measurement is carried out by making model objects based on density categories of the built-up area, namely medium, dense and very dense density.

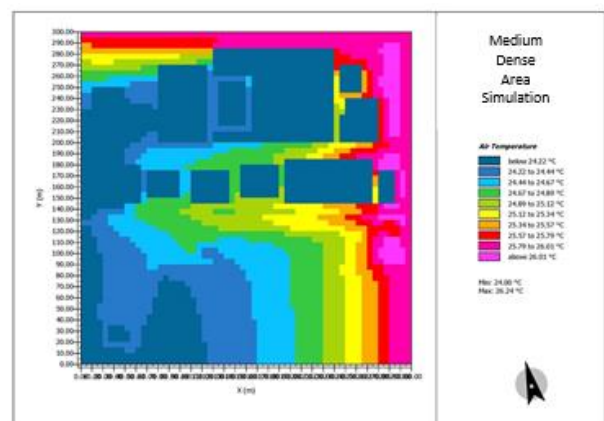


Figure 10 Surface temperature of medium density area.

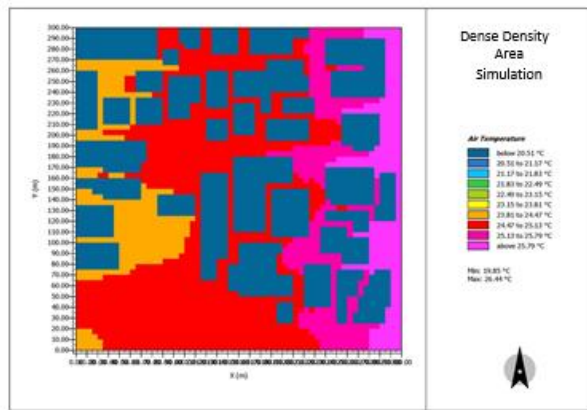


Figure 11 Surface temperature of dense density area.

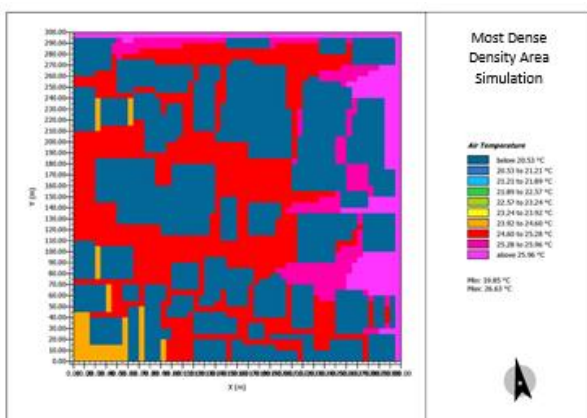


Figure 12 Surface temperature of most dense density area.

The results show that the minimum surface temperature is 19,85oC and the maximum temperature is 26,63oC. The simulation results show that areas of dense and very dense density produce higher temperatures than areas of medium density. The temperature distribution (red color) is evenly distributed in almost all areas that have dense and very dense density.

Urban heat island is a condition where the temperature in urban areas is warmer than the suburbs, which will be found in places that have extreme temperatures above 35oC [15]. After simulation using EnviMet software, the highest temperature among the three areas is 26.63°C. So, it can be concluded that the three areas have not experienced an urban heat island. However, the simulation results need to be reviewed due to the limited use of software (trial version) which may affect the analysis results.

6. CONCLUSION

The purpose of this study is to determine the characteristics of changes in the physical elements of the city due to land use changes that affect the Urban

Heat Island in Caturtunggal, Sleman Regency, Yogyakarta. Conclusions from the results of the analysis are:

Changes in land use that occurred in Caturtunggal based on the number of samples that had been identified for nine years from 2007 - 2016 were 15% (26.96 Ha) and the average change per year was 1.7% (3.30) Ha. The area of land that has not been built is 55% (106.70 Ha), in other words it can be interpreted if the land conversion is not controlled and allowed to occur continuously, it can be predicted that within 32 years the land will be exhausted. Vacant land which has a minimum area of 25-200 m2 has a high potential to be converted into built-up land compared to others.

Green open space in Caturtunggal is 17%, so that in the current situation it is possible to increase temperatures exceeding 0.4-1.8°C in the Caturtunggal area for a period of nine years. To meet the ideal condition of green open space of 40-50%, it is necessary to add 23-33% of green open space, so that it is not possible to expand horizontally, development is only possible vertically on land that has been built.

Land conversion in Caturtunggal dominantly leads to horizontal development, namely a one-story building with a sloping roof using clay tile material. Development in a horizontal direction results in a higher density level due to the closer distance. If the development in the horizontal direction is still carried out continuously, it is possible that there will be an increase in temperature that is higher than the current condition. Four of the five characteristic variables, changes in land use change in the form of decreasing green open space, the density of the built up area, roof material and the ratio of building heights tend to contribute positively to the urban heat island.

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