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Increasing Urban Heat Island area in Jakarta and it's relation to land use changes

Increasing Urban Heat Island area in Jakarta and it's relation to land use changes

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Abstract. Urban Heat Island (UHI) is a phenomenon that occurs in almost all metropolitan cities in the world. The UHI phenomenon also occurs in Jakarta, the capital city of Indonesia, a metropolitan city with an area of 662 km2, 12 million inhabitants, and an average population density of 16,000 per km2. Previous research shows the area of UHI, areas with temperatures> 300, in Jakarta in 1989 reached 84.53 km2 or 0.1 % of the total area. Based on these facts, the aim of this study is to identify changes in the area of UHI areas from 2008 to 2018 and their relation to land use changes. Temperature data used in this study are from Landsat satellite images in 2008, 2013 and 2018, while the land use data used are from National Geospatial Information Agency. Similar to the previous research, the operational definition of UHI used in this study is that UHI is the area with surface temperature > 300. The method used is spatial analysis and comparison method. The results showed that the area of UHI in Jakarta had increased. The areas of UHI Jakarta were 36.5%, 84.7%, and 85.2% of the total areas respectively in 2008, 2013 and 2018. The increases of UHI's area were in line with the increases of the built areas that respectively 79.2%, 82.9% and 85.2%. Land use for housing, commercial and services, industry and warehousing and transportation facilities seem to be more significantly affecting the increases of UHI area rather other land uses.

1. Introduction

Urban Heat Island (UHI) is a closed isotherm which shows a relatively warmer surface area in urban areas compared to the surrounding rural areas [1]. In parallel with the increasing number of population and the rapid process of urbanization, Urban Heat Island is increasingly becoming more significant in urban areas and has an impact on the deteriorating conditions of air quality and the quality of the environment, the higher use of energy will ultimately affect climate change [2-4].

The UHI phenomenon occurs in almost all major cities [5-7] in the world including DKI Jakarta, state capital of Indonesia. With a land area of 653 km2, the population of DKI Jakarta reaches around 12 million and with an average population density of 16,000 people/km^2 [8]. Research conducted by Tursilowati in 1989 showed that UHI (an area with temperature > 30°C) in DKI Jakarta was detected as large as 84.53 km2 or around 0.1% of the total area of DKI Jakarta. Other research states that the city also experienced an

increase in temperature in several locations from around 289°K - 293°K in 2007 to ≥ 293°K in 2013 [9]. Based on this phenomenon, this study aims to identify the development of UHI area in DKI Jakarta in 2008 - 2018 and to examine the relationship to the changes in land use.

2. Methods

The data used in this research is secondary data. Temperature data are obtained from Landsat Satellite Image, while land use data are collected from the National Geospatial Information Agency. The analytical method used in this study is a spatial analysis method using ArcGIS 10.0 software. Stages of data analysis carried out to map UHI is to calculate and map land surface temperature, determining UHI and non UHI areas, and analyzing the development of UHI area [10-12].

To determine whether an area is UHI or non-UHI, the maximum limit of normal temperature is utilized with an average temperature of 30^0 C [13]. An area is categorized as UHI if the temperature is > 30^0 C. The development of UHI area is analyzed by comparing the area of UHI in 2008, 2013 and 2018. Land use change analysis is done by comparing land use patterns (composition of built and non-built areas) and calculating the rate of change in each land use. Both results can be compared to descriptively identify the relationship between UHI and land use changes.

3. Results and discussion

3.1. Urban Heat Islands (UHI) area development in DKI Jakarta from 2008 to 2018

By using the operational definition that UHI is an area with temperature > 30^0, the area of UHI also increases from year to year. In 2008, the UHI area still covered 36.5% of DKI Jakarta's area or 23,846 ha, while in 2013 it jumped dramatically and cover most of the area (84.7% or 55,340.4). In 2013, almost all cities in Jakarta are categorized as UHI, so the spread of UHI 2013 – 2018 was no longer as intensive as in 2013-2018. In 2018, the area of UHI have reached to 61,820.9 ha (93.7% of the total area).

Based on the figure 1, we can see that the direction of UHI distribution starts from the central part of the city which is the center of city activity and spreaded to any direction. The spread of UHI 2008 – 2013 shows the tendency of more intensive distribution to the south. However, the expansion of UHI with temperatures above 34^0 is expanding in the eastern part of Jakarta from North to South and starting to form spreading spots in the western part of the city. This condition shows that the temperature in DKI Jakarta in general is getting higher.

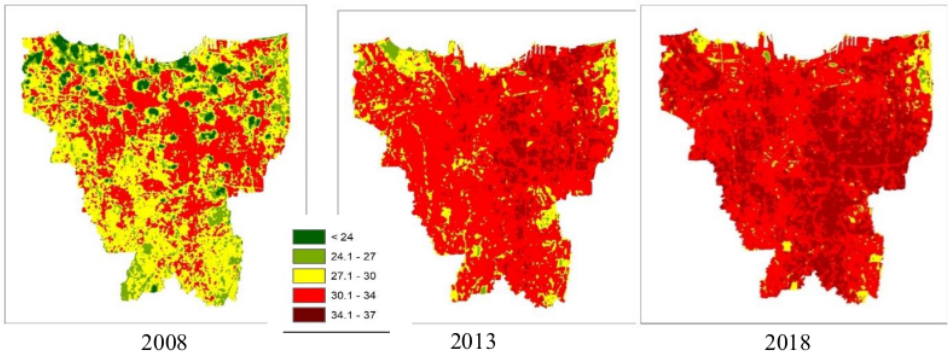

Figure 1. Land surface temperature distribution of DKI Jakarta in 2008, 2013, and 2018 [14-16].

3.2. DKI Jakarta land use change from 2008 to 2018

As the nation's capital and the largest metropolitan in Indonesia, the development of Jakarta is highly rapid, especially related to activities as the Government Center as well as the center of the national economy. As a consequence, changes in land use in DKI Jakarta are very dynamic which resulting an increasing amount of developed land. Land use data of 2008, 2013 and 2018 are presented in Table 1.

Table 1. DKI Jakarta's land use in 2008, 2013 and 2018.

LAND USE	AREA BASED ON LAND USE CATEGORY						LAND USE CHANGE	
	2008		2013		2018		2008 – 2013	2013-2018
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha/year)	(ha/year)
Government Facility	610.9	0.9%	2013.3	3.1%	1993.2	3.0%	280.48	-4.02
Social Facility	2830.9	4.3%	4468.7	6.8%	4517.0	6.9%	327.56	9.66
Transportation Facility	401.0	0.6%	969.4	1.5%	1202.8	1.8%	113.68	46.68
Industry, Warehouses	4857.5	7.4%	5474.7	8.4%	5875.6	9.0%	123.44	80.18
Commercial and Service	4377.2	6.7%	6479.7	9.9%	7154.5	10.9%	420.50	134.96
Housing	38689.1	59.2%	34802.9	53.2%	34968.1	53.5%	-777.24	33.04
DEVELOPED LAND	**51766.6**	**79.2%**	**54208.7**	**82.9%**	**55711.2**	**85.2%**		
Farm	10638.7	16.3%	6668.8	10.2%	5443.5	8.3%	-793.98	-245.06
Water	2365.4	3.6%	1724.1	2.6%	1602.3	2.5%	-128.26	-24.36
Non-Farm Green Space	592.3	0.9%	2761.2	4.2%	2606.1	4.0%	433.78	-31.02
UNDEVELOPED LAND	13596.4	**20.8%**	11154.1	**17.1%**	9651.9	**14.8%**		
TOTAL	**65363**	**100%**	**65363**	**100%**	**65363**	**100%**		

The total developed area in DKI has dominated land use in 2008 and has continued to increase in 2013 and 2018. The similarity of land use patterns in 2008 – 2018 that the land use is dominated by settlements. However, settlements tends to decrease although not significantly. This condition seems not in line with the increasing population of Jakarta. There are at least two answers to this phenomenon. First, residential areas become more densely populated with or without being followed by smaller building plots, and the second, regarding to government's policy to build Apartments. This means that the need of space for settlements for each population has become smaller, nevertheless, this decrease surely still followed by an increase in population density.

3.3. Linkage between UHI expansion and land use change

The tendency of UHI expansion and the increasing temperature in DKI Jakarta is estimated to be related to the increasingly intensive development of land changes. This is also stated by [17] that land use changes have a strong relationship with air temperature increase, the higher the level of developed land, the higher the air temperature. The trend of developed area and UHI increase in DKI Jakarta is illustrated in Figure 2.

Although showing a equal increasing trend, the increase of UHI area is much faster than the increase of developed area. These results indicate that although land use (developed area) has an influence on temperature increases land use is not the only one that influences or shapes UHIs. As [18] the intensity of UHI increases in line with the increase of urban area. In addition, the intensity of UHI is also influenced by economic activity factor in the region, geographical and seasonal characteristics, and population level. This shows that the intensity of activities and population in a city greatly influences the formation of UHI.

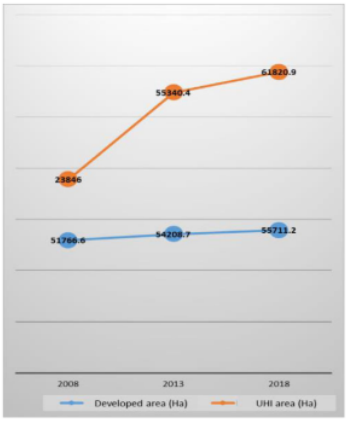

Figure 2. UHI and developed area changes overyears in 2008, 2013 and 2018.

Jakarta has a high population density of 16,000 residents/ km2 [9]. In addition, Jakarta's daily economic activities are also supported by commuter residents who inhabit surrounding cities. These economic activities which then affect the intensity of land use such as building development in Jakarta, not only horizontally but also vertically, intensity of land use for commercial and service areas, intensity of land use for transportation facilities, and so on. As stated by [19], there was a significant correlation between Surface Urban Heat Island Intensity (SUHII) and population as well as GDP in global cities. Moreover, this study suggested that the impact of population on SUHII might be stronger in the early stages of urbanization, and the GDP factor would become a critical factor at a certain development level.

Table 2 shows, the types of land use in developed areas have a more significant effect on UHI compared to the types of undeveloped areas in 2008, 2013 and 2018. However, if compared between years, it is evident that the effect all types of land use have contributed to UHI formation. This phenomenon proves that it is not only land use that affects the area of UHI. It is estimated that the intensity of each land use will increase along with the population as users and with the increase in the intensity of activities on the land.

Table 2. UHI area based on land use category in 2008, 2013, 2018.

Land Use	UHI Area (ha)			% Against Land Use		
	2008	2013	2018	2008	2013	2018
Developed Area						
Government Facility	114.27	1749.91	1836.57	18.7	86.9	92.1
Social Facility	703.06	3502.68	4128.18	24.8	78.4	91.4
Transportation Facility	184.23	919.39	1117.30	45.9	94.8	92.9
Industry and Warehouses	1848.78	5075.83	5497.36	38.1	92.7	93.6
Commercial and Service	1881.61	6399.81	7014.59	43.0	98.8	98.0
Housing	18560.31	34562.20	34714.69	48.0	99.3	99.3
Undeveloped Area						
Farm	1397.81	3709.26	4059.55	13.1	55.6	74.6
Water	255.52	495.78	678.02	10.8	28.8	42.3
Non-Farm Green Area	101.64	2016.84	2301.58	17.2	73.0	88.3

If we compare between each type of land use in developed land, these results indicate that in general, residential land use is the most influential one among other uses. Four kinds of land use namely residential, commercial and service, industry and warehousing and transportation facilities affect the expansion of UHI more significantly than land use for government facilities and social facilities. Meanwhile, in the group of undeveloped land use types, non-agricultural green area (cemetery, park, sports field) has more effect on the increase in temperature than farm land and water.

The results of this study are in parallel with a study conducted by [20]. The results of the study concluded that "the industrial-commercial areas and the high density residential areas correspond to the highest values of the land surface temperature, thus contributing to the intensification of the UHI phenomenon, regardless of the season, while the water bodies and the forests have the lowest values of the land surface temperatures, also regardless of the season." Similarly, [21] with the Singapore case study also identified that "in the daytime, the order of surface temperatures in different land uses types are industrial, commercial, airport, residential, and park respectively. However, during the night time, the order is commercial, residential, park, industrial, and airport." The finding of another study also mentions that "the change in pattern of UHI intensity varies for different cities and seasons" [18].

4. Conclusion

This study examines the phenomenon of urban heat island (UHI) in Jakarta from 2008 to 2018 and its relation to land use, and some findings can be concluded. First, the UHI phenomenon in Jakarta shows the expansion and increase in temperature intensity. The area of UHI increased in succession from 36.5% of the total area in 2008, to 84.7% in 2013 and finally in 2018 it reaches 93.7%. UHI that occurred in 2013 was dominated by UHI with temperature ranges between 30.1-34^0 C. However, in 2018 it is dominated by UHI with temperature ≥ 34.10 C. This UHI increase is in parallel with the increase of developed area, from 79.2% of the total area in 2008, to 82.9% in 2013 and 85.2% in 2018.

This study can also prove that the developed land use has more influence on UHI intensity compared to the undeveloped land use. Among the developed land uses, land use for residential, commercial and service, industry and warehousing and transportation facilities are identified to affect the UHI expansion more significantly than land use for government and social facilities. Meanwhile, in the group of types of undeveloped land use, non-farm green area (cemetery, park, sports field) has more effect on the increase in temperature than farm land and water. This study is recommended to be continued to further explore other factors such as population density, building intensity and intensity as well as the type of socioeconomic activity in each of these land uses.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7