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The Pattern of Jakarta Metropolitan Area Emissivity: A Decade Study

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Abstract - Urbanization and the increasing urban development have caused a significant impact on land-use change, especially in dense metropolitan areas. The urban heat island phenomenon, air pollution, and thermal discomfort are among the challenges that affect all aspects of the environment, social and economic. One of the significant contributors to these variables is extremely high emissivity intensity in the urban area. The lack of long-term scientific study to investigate the emissivity and urban development in the developing metropolitan cities tends to lead to aggravation of the existing urban issues. In this study, the increasing urban emissivity observed in Jakarta metropolitan area for the past decade was investigated using the Landsat 8 mapping to analyse both the urban development pattern and the resulting emissivity intensity. The results indicate that most of the studied metropolitan area indeed generates a very high emissivity, and the increase rate reported was significant to have negative impact on the overall environment. More study is however suggested for better understanding of reason why the buffer area of the city recorded higher emissivity.

Keywords: Urbanization, Jakarta Metropolitan Area, high emissivity intensity

I. INTRODUCTION

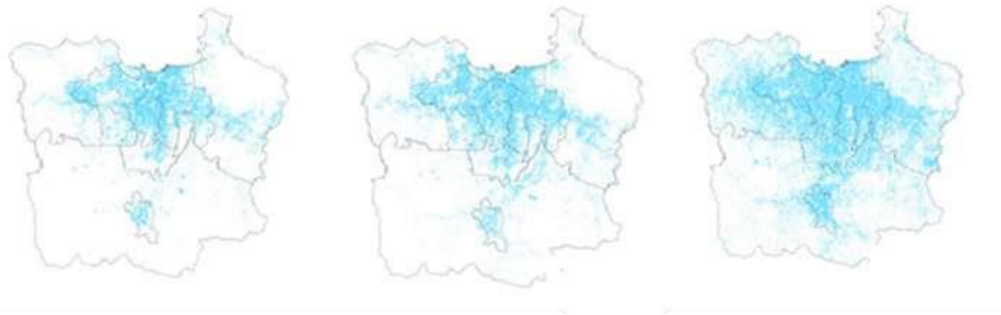
The rapid increase in population and urbanization has caused great impact on both social and environment aspect of urban life. The phenomenon that threatens our way of life in a major way is the climate change, as big cities like Jakarta struggles to face the significant temperature increase, thermal discomfort and high energy demand. Jakarta as the capital city expands to great metropolitan area that also covers the neighbour provinces [1]. With the fast-economic activities, Jakarta Metropolitan Area (JMA), locally known as Jabodetabek deals with overpopulated city centre and environmental degradation [2]. The increasing economic activities in the city centre and rapid development that includes growing infrastructures, transportation networks and facilities, development of new industrial and commercial buildings, the horizontal and vertical extension of the city development has indeed resulted into great environmental change [3- 5].

The increasing urban emissivity that contributes to the anthropogenic heat level has caused damaging impact on the urban environment. Studies have shown that increasing air pollution would undoubtedly results into serious health problem [6, 7]. Around 57.8% of Jakarta's dwellers were reported of being suffering from illness caused by poor air quality while Indonesia was ranked among the top eight global premature mortality rates correlates to air pollution [8]. The significant modification of local microclimate, precipitation and rainfall in Jakarta due to the urban activities in Jakarta has continuously become issue for the past century [2]. These microclimate challenges ought to be given adequate attention to proffer necessary strategic solutions. Therefore, this study evaluates the emissivity development over the past decade using quantitative spatial approach.

II. LITERATURE REVIEW

The rapid increase of Urban Heat Island (UHI) intensity and climate change is a long-term consequence in big cities [9-11]. The distressed urban energy balance by the significant increase of urban development and activities has caused the great burden on the urban thermal comfort and energy demand [12-15]. This situation moves the cities away from the sustainability framework and agenda. Studies on the strategic solutions to mitigate the environmental impact has been explored including for buildings urban scales [16, 17]. Technically, the increase of urban economics is the root cause of development of anthropogenic heat emission in urban area [18]. The high radiative energy is mainly influenced by the poor surface albedo and emissivity in urban area [19]. Two main contributors of the UHI increase are the land cover change [20] and the anthropogenic heat.

Jakarta is facing this challenge. The land surface of Jakarta is consistently increasing due to the urban growth and development. The change of land use covers (Normalized Difference Vegetation Index or NDVI) and the built-up area (Normalized Difference Build-up Index or NDBI) has significantly influenced the intensity of the UHI [21]. The study [21] also stressed that the emissivity of Jakarta has significantly increased in the city centre, Main Street and residential area. JMA grew significantly on both demographic and physically. According to the record from Indonesia Central Bureau of Statistics (2019), the population of JMA increased over 135% from 1980 to 2010 [22]. The data also reported that the population growth in the buffer zones (data recorded in Bogor, Tangerang and Bekasi) was higher compared to the city centre of Jakarta. Other study [23] also presented that the physical development JMA was also significant from 2000 to 2015 (Fig. 1). Meanwhile, Fig. 2 indicated that the settlement development of JMA greatly expanded in the buffer zones instead of the Jakarta city centre [24].



(2000) (2006) (2015)

Fig. 1: The development change of Jakarta Metropolitan Area in 2000, 2006, 2015 [23]

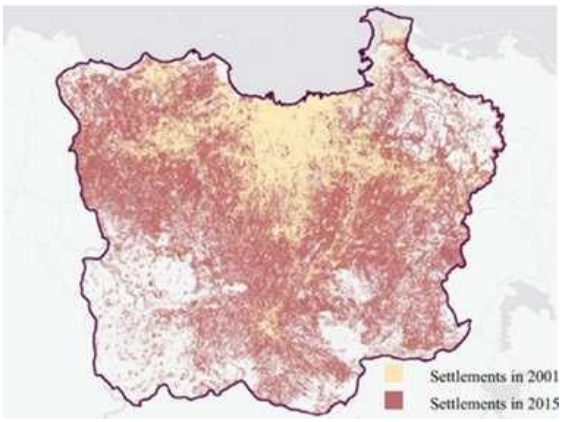


Fig. 2: The development settlement of Jakarta Metropolitan Area in 2001 and 2015 [24]

The data on JMA population and settlement shows that the concentration of population focused on the buffer zones. In this context, this study emphasizes that this situation happened due the high land and property prize issue in the city centre that creates the trend of middle-class buffer zone housings. For this reason, the high intensity of anthropogenic heat also occurred in the main street as the centre point of daily commuting activity between the buffer zones and the Jakarta city centre.

III. METHODOLOGY

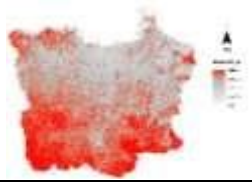
This spatial study focused on the JMA; Jakarta city centre and the buffer areas of Bogor, Depok, Tangerang and Bekasi. The total area covers 6,343 km^2 and 35.426 million population in 2020 (Jakarta Central Bureau of Statistics, 2020). The decade spatial analysis was performed for year 2009 and 2019. The Landsat 8 of year 2009 and 2019 data were analysed to present the development of the urban surface emissivity. Besides the comparison of a decade data, this study broke down the emissivity analysis into five scales intensity. The five scales emissivity (ε) units are very high (0.990104), high (0.982578), moderate (0.975052), low (0.967526) and very low (0.960000). The analysis of the five scales emissivity (ε) units was performed by comparing the percentage of emissivity gap of the five scales. The comparison of the decade data and the five scales emissivity emphasise the development rate of the emissivity in JMA.

IV. RESULTS AND DISCUSSIONS

The spatial analysis of this study emphasises the emissivity development of JMA from 2009 to 2019. With the ranges of emissivity (ε) unit of 0.990104 to 0.960000, the total emissivity of JMA (6,343 km^2) was reported increased from 10,855.46 to 378,353.73. A 3,385% was a great increase for a decade emissivity of the JMA. The spatial distribution mapping presents that there were range of the emissivity scales expanded greater over others. This study highlights the pattern of emissivity expansion in the JMA over a decade. Specifically, the highest emissivity expands massively from the buffer zones toward the city center in 2019.

Table 1 shows the layering analysis of emissivity distribution mapping of JMA in 2009 and 2019 according to emissivity units and scales. The mapping shows that the increase of emissivity varies in different scales. Quantitatively, Table 2 presents the four range of emissivity units and scales. The data clearly illustrated that the emissivity expansion occurred in the range of 'very high' (0.990104) to 'high' (0.982578). This situation was found different in other three ranges from 'high' (0.982578) to 'very low' (0.960000), where the emissivity value was all decreased. This pattern explains the 3,385% extreme increase of emissivity over a decade in JMA.

Table 1: The Emissivity Distribution by Range of Emissivity Units and Scales in 2009 and 2019

No.	Emissivity (ε) Units and Scales	Emissivity Mapping for a Decade	
		2009	2019
1.	0.990104 (very high)		
2.	0.982578 (high)		
3.	0.975052 (moderate)		

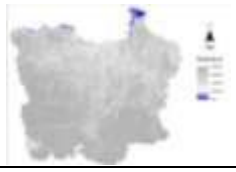
4.	0.967526 (low)		
5.	0.960000 (very low)		

Table 2: The Pattern of Emissivity Increase in 2009 and 2019

No	**Range of Emissivity (ε) Unit**	**Emissivity Scale**	**The Percentage and Area of Emissivity**			
			2009		2019	
			Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)
1	0.990104 – 0.982578	very high – high	53.87	3,417	62.68	3,976
2	0.982578 – 0.975052	high – moderate	28.08	1,781	27.77	1,761
3	0.975052 – 0.967526	moderate – low	16.39	1,040	8.65	549
4	0.967526 – 0.960000	low – very low	1.66	105	0.90	57
Emissivity (ε) by Year			10,855.46		378,353.73	
The emissivity increases for the past decade			3,385%			

Furthermore, the data also indicated that the expansion of the 'very high' emissivity scale was mapped in Depok, Bogor and Bekasi. This situation was seen as a phenomenon that the high anthropogenic heat does not just apply in the high-density city center, but also in the buffer zones. This data was correlated with the high expanding concentration of population and settlement of JMA in the buffer zones. As result, the environmental degradation especially on dealing with the high intensity of emissivity occurred in the buffer zones

V. CONCLUSIONS

The evaluation of the different layers data obtained from Landsat 8 and the spatial analysis has shown that the urban emissivity in JMA developed significantly over the last decade. This emissivity has been noted to have occurred at the highest range of emissivity scale. However, it is noteworthy that this study observed that this significant increase in emissivity does not occurs in the city center but the buffer area. Therefore, the result of this study should be subject to further analysis to understand the relationship between urban development and emissivity increase. Also, further study on any correlation between the urban population and land use change within the same time frame is suggested may additional information necessary for framing a sustainable city-built environment by urban planners and policy makers as JMA continue to grow in population and development.

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