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A COMPARISON OF ESTIMATED LAND SURFACE TEMPERATURE FROM LANDSAT 8 BETWEEN DKI JAKARTA AND PEKAT VILLAGE

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Abstract. *Land Surface Temperature (LST) shows the general temperature condition of environment and many factors may affect it such as weather, cloud coverage, and sun exposure time. During the Corona Virus pandemic, Indonesia implemented the Pemberlakuan Pembatasan Kegiatan Masyarakat (PPKM) system that restricted many activities and suspected of influencing LST in one or another way. PPKM system itself does not cover every province in Indonesia; thus, it is suspected that LST between areas either do or do not implement PPKM may differ. This paper aims to map and analyze LST between Jakarta Province and Pekat Village before and during implementation of PPKM using descriptive research method with a quantitative approach. The results show that there is a significant temperature change in Jakarta when the PPKM level changes transpires. Pekat Village also experiences temperature changes although it is not affected by PPKM system. Even though there are some data anomalies, the temperature changes are within expectation. Therefore, this concludes that PPKM brought some slight effects toward LST and its changes.*
Keywords: Land surface temperature, Remote sensing, Jakarta Province, Pekat Village

1. **Introduction.** Land Surface Temperature (LST) is one of the most essential elements in governing the land surface energy budget such as surface energy and water balance, because it is the direct driving force in the interchange of long-wave radiation and unstable heat fluxes at the surface atmosphere interface [1-6]. It anchors the atmospheric humidity profile, as well as the availability of surface moisture (i.e., surface conductivity or resistance). Hence, LST is a critical boundary condition for sensible heat and water vapor fluxes into the sky, as well as soil heat fluxes into the earth [3].

Indonesia's government implemented a system in attempt to limit and decrease the spread of Corona Virus called *Pemberlakuan Pembatasan Kegiatan Masyarakat* (*PPKM*) or Imposition of Restrictions on Community Activities [7]. This policy includes several limitations and conditions, such as the implementation of Work from Home (WFH) and Work from Office (WFO) from a selected sector, as well as restrictions on several activities and non-work related sectors [8]. Based on these limitations and conditions, there are many activities and daily actions affected, leading to reduction in outdoor activities that is suspected to affect LST in DKI Jakarta that is directly affected by *PPKM*, and as a comparison, an area not affected by *PPKM* namely Pekat Village is analyzed to determine whether *PPKM* may be an additional cause to LST and its changes. Previous researches do not account *PPKM* as a factor to estimate LST, since *PPKM* itself has not been implemented in the previous years. The goal of this research is to map and analyze LST between DKI Jakarta Province and Pekat Village before and during implementation of

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PPKM with the aim to determine the influence of *PPKM* towards LST and the difference with an area that does not experience *PPKM*. The estimation and analysis of LST as well as the effects of *PPKM* on it will be discussed in this paper. Therefore, it is hoped that through this research, it is possible to provide information regarding factors that affect LST, effect of *PPKM* changes towards LST, and general differences of LST between urban and rural areas. These pieces of information can be considered for further research.

This paper is categorized as follows: Section 2 describes the methodology, Section 3 describes the result and discussion, and Section 4 describes the conclusion.

2. **Methodology.** Research process starts after the problem was identified. The data that had been gathered was being pre-processed by calculating the land surface temperature (LST). Subsequently, the pre-processed data was being processed by classifying the temperature range and estimated area size. Lastly, the result was being analyzed and compared between DKI Jakarta Province and Pekat Village. The research process is shown in Figure 1.

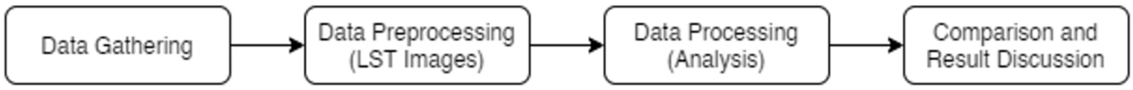


Figure 1. Research process

2.1. **Data preprocessing.** The dataset was being preprocessed by calculating the land surface temperature with 6 steps using Quantum Geographic Information System (QGIS).

The first step is converting from the Thermal Infra-Red Digital Numbers to Top of Atmosphere Spectral Radiance (TOA). TOA can be considered as lights reflected from the land surface and is measured from the atmosphere. The formula used to calculate TOA Spectral Radiance ($L\lambda$) is as follows [9,10]:

$$L\lambda = M_L * Q_{cal} + A_L - O_i, \tag{1}$$

where M_L is the band-specific multiplicative rescaling factor, while Q_{cal} is band 10 image itself, A_L is the band-additive rescaling factor, and O_i is the correction for band 10.

Next, Brightness Temperature (BT) is needed to calculate real land surface temperature, by applying thermal constants of the corresponding bands to convert TIRS Band Data to BT [9]. The BT formula used to convert radiance to BT is as follows [6,9-11]:

$$BT = \frac{K2}{\ln\left[\left(\frac{K1}{L\lambda}\right) + 1\right]} - 273.15, \tag{2}$$

where $K1$ and $K2$ are the respective band's thermal conversion constants provided in the metadata file of the satellite imagery, $L\lambda$ is the TOA Spectral Radiance which is calculated in (1), and to output the results in Celcius, the radiant temperature must be revised by applying absolute zero of approximately -273.15°C.

After BT is obtained, the Normalized Difference Vegetation Index (NDVI) is calculated, where it is a dimensionless index that can be used to measure green density on an area [12]. NDVI is an essential value, since NDVI is highly related to the Proportion of Vegetation (P_v) and emissivity (ε) which are used in land surface temperature calculation [9,10]:

$$NDVI = \frac{NIR(band\ 5) - R(band\ 4)}{NIR(band\ 5) + R(band\ 4)}, \tag{3}$$

where NIR is the near-infrared band ($band$ 5) and R is the red band ($band$ 4).

NDVI is necessary to calculate P_v, where it is the ratio of the vertical projection area of vegetation on the ground [13]. The NDVI value is used to calculate P_v which is determined using the following formula [9,10]:

$$P_v = \left(\frac{NDVI - NDVI_s}{NDVI_v - NDVI_s}\right)^2, \tag{4}$$

where the $NDVI_v$ is the vegetation threshold (maximum NDVI value) and $NDVI_s$ is the soil pixel threshold (minimum NDVI value) where both thresholds can be obtained from (3) since the output is a series of numbers.

Afterwards, the emissivity must be estimated, either simultaneously or from external data sources, in order to extract the land surface temperature [14]. The ratio of the radiance emitted by a surface to the radiance emitted by a black body at the same temperature is known as the emissivity [15,16] which is computed as follows [9,17]:

$$\varepsilon_\lambda = \varepsilon_{v\lambda} P_v + \varepsilon_{s\lambda}(1 - P_v) + C_\lambda, \tag{5}$$

where $\varepsilon_{v\lambda}$ and $\varepsilon_{s\lambda}$ represent the vegetation and soil emissivity, respectively, P_v represents the Proportion of Vegetation which is calculated in (4), and C_λ represents the surface roughness.

Finally, Land Surface Temperature (LST) is calculated and is made from a combination of vegetation and bare soil temperatures, because both respond quickly to change in incoming solar radiation caused by cloud cover and aerosol load alterations, as well as diurnal variation in illumination [18]. Thus, LST is calculated using the following formula [9,19]:

$$T_s = \frac{BT}{\{1 + [(\lambda BT/\rho) \ln \varepsilon_\lambda]\}}, \tag{6}$$

where T_s is the LST in Celcius (°C), BT represents Brightness Temperature which is calculated in (2), λ is the wavelength of emitted radiance, ε_λ represents the emissivity calculated in (5), and

$$\rho = h\frac{c}{\sigma} = 1.438 \times 10^{-2} \text{ mK} \tag{7}$$

where σ is the Boltzmann constant (1.38×10^{-23} J/K), and c is the light velocity (2.998×10^8 m/s) [18].

2.2. **Data processing.** After the dataset has been preprocessed, the next step was to process the result from previous step using QGIS. Areas not related to the observed area have to be excluded in order to perform accurate analysis and calculation. The first step was to use QGIS's built-in raster extraction feature to extract each layer (masking) of the resulting LST images from the available shapefiles for Jakarta Province and Pekat Village. For Jakarta Province, there were 5 extracted layers consisting of North, South, West, East, and Central Jakarta, while there was only 1 extracted layer for Pekat Village. After all layer was extracted, the LST unique value table of each layer was generated using QGIS's built in function, which shows each temperature value (in Celsius) with its corresponding area size. Lastly, report analysis result was grouped and calculated based on a defined temperature range.

3. Result and Discussion.

3.1. **Study area.** DKI Jakarta Province and Pekat Village, Dompu District, West Nusa Tenggara Province are chosen for this research. The used data were taken from the Landsat Data Collection and to be exact from Landsat 8 OLI/TIRS Collection 2 Level-2 satellite imagery result. Selected data from the satellite will be overall cloud free since the presence of clouds will affect land surface temperature such as the cloud's temperature itself or the reflection of radiation caused by it. Based on Table 1, path row for Jakarta Province will be from 122 to 064, while for Pekat Village it will be from 115 to 066. There will be 2 selected dates of taken data from each *PPKM* implementation, except *PPKM* level 3, there will be only one date of taken data due to the fact that the presence of cloud cover at the time of *PPKM* level 3 was implemented. There will also be a difference of 1 day

TABLE 1. Dataset

	DKI Jakarta Province	Pekat Village
Path row	122-064	115-066
Before *PPKM*	2020/07/27 03:00:16	2020/07/26 02:17:48
	2020/10/15 03:00:41	2020/10/14 02:18:13
PPKM level 4	2021/04/25 02:59:57	2021/04/24 02:17:30
	2021/05/11 02:59:53	2021/05/10 02:17:24
PPKM level 3	2021/09/16 03:00:38	2021/09/15 02:18:10

for date of taken data for Jakarta and Pekat Village due to Landsat 8 data retrieval time cycle.

3.2. **Results.** Below are the tables showing calculations of several predefined temperature classes of 3 degree range for each range, starting from temperature below 20.0°C considered as measurement error and final range of temperature between 32.0°C to 34.9°C. Temperature range of 3 degree each, estimated area size area both in (km^2) and (%) are determined based on the purpose of showing an evenly distributed temperature ranges to calculate each class's estimated area size and the respective percentage for further analysis.

TABLE 2. Before *PPKM* table results

Temperature range (°C)	Jakarta Province				Pekat Village			
	27th July 2020		15th Oct. 2020		26th July 2020		14th Oct. 2020	
	km^2	%	km^2	%	km^2	%	km^2	%
< 20.0°C	16.82	2.62%	97.22	15.14%	2.54	11.66%	0.99	4.56%
20.0°C-22.9°C	17.14	2.67%	63.53	9.89%	12.22	56.14%	5.12	23.51%
23.0°C-25.9°C	113.75	17.72%	181.65	28.29%	6.96	31.95%	7.15	32.83%
26.0°C-28.9°C	407.75	63.51%	274.35	42.73%	0.05	0.25%	7.43	34.10%
29.0°C-31.9°C	86.45	13.46%	25.30	3.95%	0.00	0.00	1.06	4.87%
32.0°C-34.9°C	0.14	0.02%	0.01	0.00	0.00	0.00	0.03	0.13%

TABLE 3. During *PPKM* level 4 table results

Temperature range (°C)	Jakarta Province				Pekat Village			
	25th April 2021		11th May 2021		24th April 2021		10th May 2021	
	km^2	%	km^2	%	km^2	%	km^2	%
< 20.0°C	34.95	5.44%	0.32	0.05%	0.24	1.09%	0.03	0.15%
20.0°C-22.9°C	76.33	11.89%	0.35	0.05%	4.04	18.58%	13.46	61.82%
23.0°C-25.9°C	337.59	52.58%	36.99	5.76%	14.19	65.15%	7.73	35.52%
26.0°C-28.9°C	187.74	29.25%	293.47	45.71%	3.27	15.03%	0.55	2.51%
29.0°C-31.9°C	5.42	0.84%	309.85	48.26%	0.03	0.15%	0.00	0.00
32.0°C-34.9°C	0.02	0.00	1.07	0.17%	0.00	0.00	0.00	0.00

3.3. **Discussion.** According to Table 2, there is a decrease in temperature of Jakarta Province from 27th July to 15th October 2020. At 27th July, approximately 90% of the temperature coverage are between 23.0°C to 31.9°C, whereas at 15th October they are between 20.0°C to 28.9°C. Based on weather information [20], the weather in Jakarta at

TABLE 4. During *PPKM* level 3 table results

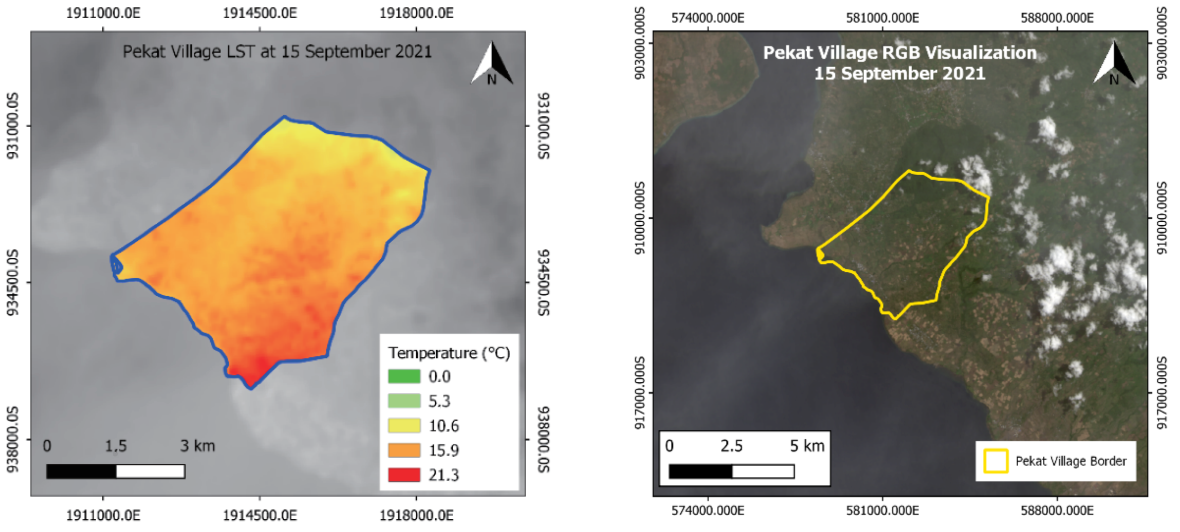
Temperature range (°C)	Jakarta Province		Pekat Village	
	16th September 2021		15th September 2021	
	km^2	%	km^2	%
< 20.0°C	3.32	0.52%	21.59	99.14%
20.0°C-22.9°C	19.74	3.07%	0.19	0.86%
23.0°C-25.9°C	158.52	24.69%	0.00	0.00
26.0°C-28.9°C	423.46	65.95%	0.00	0.00
29.0°C-31.9°C	36.97	5.76%	0.00	0.00
32.0°C-34.9°C	0.04	0.01%	0.00	0.00

27th July 2020 during daytime was scattered cloud while at 15th October 2020 was partly sunny; hence, sun exposure at 27th July 2020 is higher. On the other hand, Pekat Village experienced an increase in temperature from 26th July to 14th October 2020, where there are slight changes of temperature class coverage from between 20.0°C to 28.9°C at 26th July to between 20.0°C to 28.9°C at 14th October, not in line with weather condition of passing clouds at 26th July 2020 and scattered cloud at 14th October 2020. The two weather condition shows similar features, yet temperature wise shows an increase.

Based on Table 3, the temperature in Jakarta Province increased from 25th April to 11th May 2021, with approximately 90% of the temperature coverage changed from between 20.0°C-28.9°C to between 26.0°C-31.9°C. Based on weather information [20], the weather in Jakarta on 25th April during daytime was partly sunny and the weather on 11th May during daytime was scattered cloud. Meanwhile, Pekat Village's temperature decreased from between 20.0°C-28.9°C on 24th April to between 20.0°C-25.9°C on 10th May. The weather in Pekat Village on 24th April was scattered cloud and the weather on 10th May was passing cloud. These show that Jakarta experienced an increase in temperature during the same time period, whereas Pekat experienced a decrease, which is the polar opposite of before *PPKM*.

The LST of Jakarta at 16th September 2021 and Pekat Village at 15th September 2021 was shown in Table 4. Jakarta's LST is dominated by approximately 90% between 23.0°C and 28.9°C. On the other hand, Pekat Village's LST is dominated by more than 90% of temperature lower than 20.0°C. That inconsistency is considered as a measurement error and is suspected to be caused by a large extent of cloud coverage. According to weather information [20], Pekat Village at 15th September 2021 is partly sunny. As shown in Figure 2(a), Pekat Village's temperature was abnormally low. Figure 2(b) shows the RGB visualization of Pekat Village to further analyze the temperature anomaly, where some cloud coverage was detected.

Based on Figure 3, there was a slight decrease in temperature from 27th July 2020 to 15th October 2020. In comparison with data retrieved from Climate Knowledge Portal [21], the pattern of precipitation in DKI Jakarta shows a slight increase, therefore the slight decrease of temperature is expected due to precipitation amount, while in the mentioned date, *PPKM* has yet to be applied. Temperature decreases are also expected on 25th April 2021, compared to data from [21]. Meanwhile, there is a large temperature increase from 25th April 2021 towards 11th May 2021 with a massive temperature class shift from a majority of around 20°C to 28.9°C to around 26°C to 31.9°C. Compared to data from [21], precipitation amount around these months only shows a slight decrease, yet *PPKM* level 4 is being applied. Temperature shifted from the 11th May to 16th September 2021, from a majority of 26°C-31.9°C to a majority of 23°C-28.9°C, which is not consistent



(a) (b)

Figure 2. (color online) Pekat Village, 15th September 2021 (a) LST visualization and (b) RGB visualization

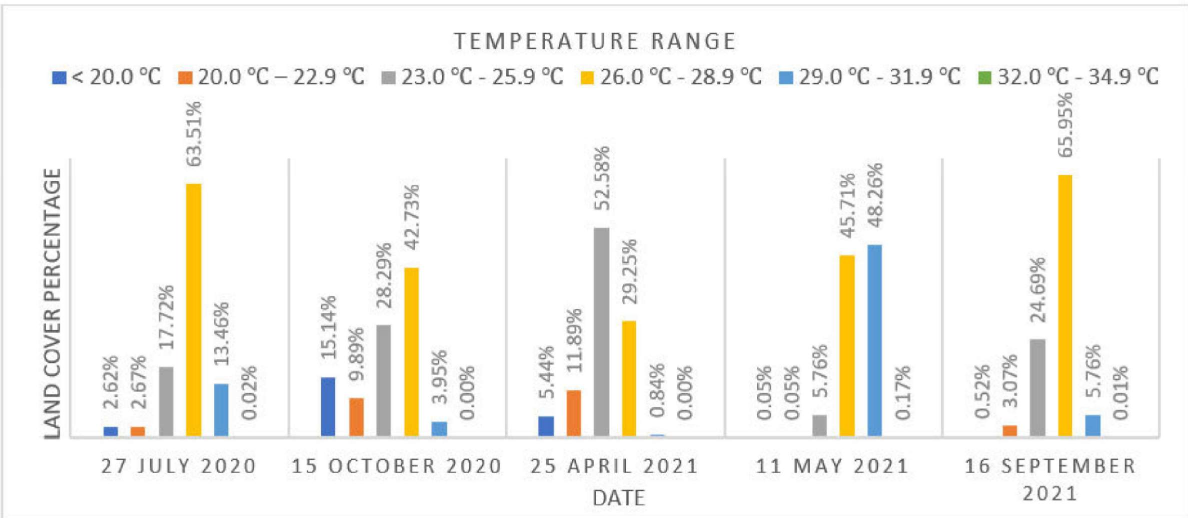


Figure 3. Jakarta temperature range to estimated area size changes graph

with the precipitation pattern. The *PPKM* implementation has also shifted from level 4 to level 3 between the mentioned date.

Besides that, the land surface temperature changes in Pekat Village were fluctuating which is shown in Figure 4. From 26th July 2020 to 14th October 2020, there is a slight increase in temperature between 20.0°C to 25.9°C towards 20.0°C to 28.9°C. In comparison to the data from Climate Knowledge Portal [21], the precipitation pattern in Pekat Village shows a slight increase in precipitation amount. This can happen because the weather condition can affect the precipitation. Temperature shift also happened between 24th April to 10th May 2021 which is a decrease, but they are inversely proportional to precipitation amount because the precipitation amount shows a decrease of value, so there should be a slight increase of LST. According to Weather Information [20], the weather in Pekat Village at 24th April 2021 is scattered clouds, whereas 10th May 2021 weather is passing clouds; thus, there is a chance that cloud cover affected the LST measurement,

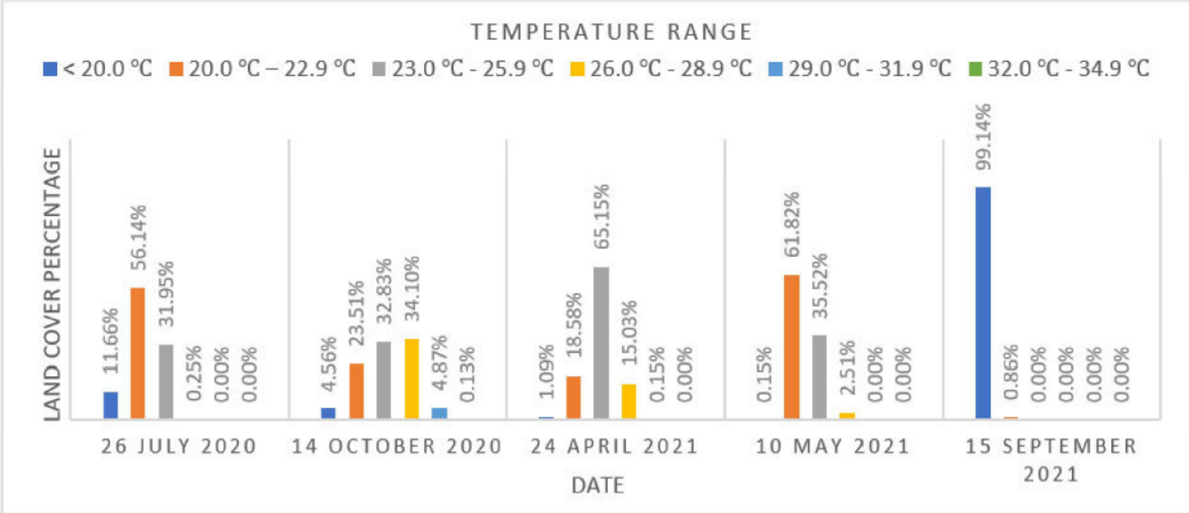


Figure 4. Pekat Village temperature range to estimated area size changes graph

causing the temperature decrease. Meanwhile, the temperature shift between 10th May to 15th September 2021 is irrelevant since analysis in Section 3.3 shows that LST of Pekat Village at 15th September is considered to be anomaly data due to the mass cloud coverage.

4. **Conclusion.** The *PPKM* system implemented on Jakarta caused small effects on Land Surface Temperature (LST) changes. The aims of this paper are to map and analyze the LST changes in Jakarta affected by *PPKM* and indirectly compare to a rural area that is not affected with *PPKM*, namely Pekat Village. By utilizing the methods in Section 3, the results show that there is a significant temperature change in Jakarta according to comparison between estimated area size per temperature range towards precipitation amount. Furthermore, there are also temperature changes in Pekat Village although there are anomalies, but the temperature changes are within expectation. Based on data analysis, *PPKM* brought some slight effects toward LST and its changes, where the expected temperature and the observed temperature show several differences in terms of temperature range coverage of the observed area. Compared to *PPKM* levels and changes, precipitation plays a more important role in influencing LST and its changes; therefore, precipitation has a high correlation with LST while *PPKM* levels have a small correlation on LST.

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