Exploring the relationship of solid waste height and land surface temperature in municipality landfill site using Unmanned Aerial Vehicle (UAV) images

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Abstract. Increasing solid waste volume from human activities makes solid waste stockpiles grow higher in municipal landfill site. This phenomenon has potential risk especially in form of increasing land surface temperature (LST) when compared to surrounding environment. However, detailed survey of LST in solid waste piles using conventional tools might be time-consuming. Therefore, this study offers alternative of elevation and LST measurement in waste piles using combined images from unmanned aerial vehicle (UAV) and Landsat 8. Herein, DJI Phantom 4 Pro was flown in a waste stockpile located in Cipayung landfill site, Depok Municipality, Indonesia. Digital Surface Model (DSM) was acquired from UAV images processing. LST prediction is processed from Landsat 8 thermal infrared sensors (TIRS) band 10. Resampling technique was employed to match spatial resolution between DSM and LST. Both solid waste elevation and LST were paired statistically using Pearson correlation coefficient to observe linear relationship between them. Results show that waste elevation and LST have positive correlation.

1. Introduction
The increasing usage of unmanned aerial vehicle (UAV) in Indonesia has enabled detail mapping application for variety of implementation. Particularly, in the field of municipal solid waste (MSW), where its environmental impact to surrounding environment is critically monitored both by MSW management and other parties such as NGO and academicians. Related to this, previously researches involving UAV for detail mapping in MSW sites has successfully measured solid waste volume and height [1].

In addition, topics of land surface temperature (LST) in MSW sites have got many intentions. One of the interesting topics is how to relate the increasing amount of solid waste with the LST [2]. The information comes from this can give early warning to MSW managers on how to avoid increasing LST within waste stockpile. Many years ago, a landslide disaster in Leuwigaiaj disposal site was suspected because of increasing amount of solid waste [3]. This potential disaster because of increasing amount of solid waste in MSW can be avoided if MSW managers have the opportunity to predict when stockpile becomes dangerous. However, measuring LST within solid waste stockpile can be dangerous for survey personnel due to slope instability of the stockpile. Therefore, UAV operation to capture images of MSW stockpile is profitable. This operation can capture images of MSW stockpile with fast and safely. Hence, this article aims to describe the relationship between MSW stockpile elevation and LST using images from UAV.
1.1. Study area
Cipayung landfill site is located in Depok Municipality, West Java Province, Indonesia. It can be reached approximately 1 hour from Indonesia’s capital city of Jakarta. Administratively, its location within Pasir Putih Village inside the Cipayung sub-district (Figure 1). It has an area of around 6.77 hectares.

2. Methods
Comprehensive research flowchart can be seen in Figure 2. In this study, DJI Phantom 4 Pro was flown at 150 m height to capture image and elevation of Cipayung landfill site. After images were acquired, it underwent processing steps within Agisoft Photoscan software. The next step was to perform geometric correction for processed images using Google Earth image served as ground truth coordinates. Spatial resolution of the image after geometric correction is 2.64 cm/pixel. This processed image was used to delineate solid waste stockpile and functioned as a mask to clip Digital Surface Model (DSM) and temperature raster data.

For LST generation, at first digital number (DN) of band 10 from Landsat 8 was converted into top of atmospheric (ToA) reflectance values. These ToA values were further computed to generate temperature
values at Celcius degree. Temperature values were paired with elevation values extracted from DEM data. These paired data then analyzed using regression analysis to observe their relationship.

2.1. Elevation modelling from UAV
Point Cloud data acquired from UAV flight operation were further compiled to generate DSM. The process to provide DSM from UAV data was performed using Agisoft Photoscan. DSM product was in raster value showing elevation (meter) in each pixel. To predict the height of solid waste stockpile, Street View menu in Google Earth was used to set 0 m location which was located in the entrance of Cipayung landfill site. This location then set as 0 m and calibrated with DSM raster value to estimate the height of the waste stockpile.

2.2. Land Surface Temperature
Band 10 from Landsat 8 TIRS Path 122 Roth 64 was downloaded from Earth Explorer website. The date of acquired Band 10 was 22 May 2019. The spatial resolution of the image is 30 m x 30 m per pixel.

In this study, LST was calculated using two step. Firstly, the digital number of Landsat 8 band 10 was converted to become radiance value at atmosphere (ToA) $L_\lambda$ with following equation [4,5]:

$$L_\lambda = M_\lambda Q_{cal} + A_\lambda$$  \( (1) \)
where $M_l = \text{the band-specific multiplicative rescaling factor} \ (3.342 \times 10^{-4})$, $Q_{cal} = \text{the band 10 image}$, $A_l = \text{is the band-specific additive rescaling factor} \ (0.1)$.

Secondly, spectral reflectance value needed to be converted into temperature in Kelvin degree using constant value of $K_1$ and $K_2$ from Band 10 metadata information [4,5]:

$$BT = K_2 / \ln \left[ \left( \frac{K_1}{L_{\lambda}} \right) + 1 \right] - 273.15$$  \hspace{1cm} (2)

where $BT = \text{satellite temperature in absolute temperature}$, $K_1$ and $K_2 = \text{the band 10 specific thermal conversion constants from the metadata}$.

### 2.3. Correlation analysis using Pearson Coefficient

Correlation analysis between solid waste elevation and LST in this study was conducted using Pearson correlation coefficient ($r$). Formula to compute $r$ [6] can be written in following equation:

$$r = \frac{n \sum xy - (\sum x)(\sum y)}{\sqrt{(n \sum x^2 - (\sum x)^2)(n \sum y^2 - (\sum y)^2)}}$$  \hspace{1cm} (3)

where $x = \text{solid waste elevation} \ (m)$, and $y = \text{LST} \ (^{\circ}C)$. In addition, $r$ value ranges between -1 and 1. If $r$ is positive, it means increasing elevation will increase LST. Meanwhile, if $r$ is negative it indicates that increasing elevation will decrease LST.

### 3. Results and Discussions

Using Google Earth image, it was able to determine the position of 0 m to calibrate the real solid waste height from bottom to peak (Figure 3).

![Figure 3](image)

**Figure 3.** (a) aspect of solid waste elevation, (b) 0 m elevation location (photo source: Google Earth).

It can be observed in Figure 4 that the study area is dominated with high LST ranges from 29.5\(^{\circ}\)C to 31.4\(^{\circ}\)C (red color). In addition, surrounding area of Cipayung landfill site which has vegetation, the LST tend to decrease compared to LST in study area.
When $x$ and $y$ values from the DSM and the LST raster data were input into Equation (3), the computation step can be shown as follows:

$$r = \frac{(90 \times 37776.26) - (1274) \times (2632.17)}{\sqrt{(90 \times 22608) - (1274)^2 \times (90 \times 77167.62) - (2632.17)^2}} = 0.56$$

The computation of Pearson’s $r$ shows that $r$ is 0.56. There are three main sources that can be used to interpret $r$ value [7], if $r = +0.5$ it means that the relationship can be moderate, strong, and fair. Since 0.56 can be rounded up to 0.6, it means based on [8], the strength of linear relationship between solid waste elevation and LST can be identified as moderately strong.

However, the linear equation shows that $y = 0.1129x + 27.648$ with $R^2=0.31$ where $y = \text{LST}$ and $x = \text{solid waste elevation}$ (Figure 5). According to $R^2$ value it can be interpreted that this linear model can only explain around 31% or there might be another factor for causing the increasing of LST ($y$).
Therefore, for future study another factor should be added to explain the increasing of LST beside solid waste elevation.

4. Conclusion
In this study, UAV has successfully captured the images of Cipayung landfill location with very high spatial resolution. In addition, DSM data generated from UAV platform has provided detail elevation data. However, pre-processing steps to acquired images from UAV must be done to ensure the quality of the data. Moreover, DSM should be calibrated first to obtain 0 m elevation position in order to predict the height of solid waste stockpile. The linear relationship between solid waste elevation and LST for this study can be indicated as moderately strong. Carefully noted, that the linear model used in this article can only explain 31% to the increasing LST phenomenon.

5. References
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Acknowledgments
This study is fully funded by 2019 Student’s Final Thesis Indexed Grants (Hibah PITTA-bahasa) from University of Indonesia.