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Estimation of Makassar's Landfill Surface Temperature and Its Surroundings Using Remote Sensing

ZA Hanami[1*], AD Damayanti[1], T Takeda[2], H Alimuddin[1]

[1]Department of Environmental Engineering, Universitas Hasanuddin, Makassar, Indonesia
[2]Japan Space Systems, Japan

Email: zaraharwienyhanami@unhas.ac.id*

Abstract. Remote sensing is one of the cost and time-effective methods that can be used to assess change in the land, especially the land surface temperature and land cover. This study aims to estimate Makassar's landfill surface temperature as a vital waste management monitoring parameter and the surrounding area using remote sensing. The Landsat 5 and Landsat 8 data in the years 2006, 2009, 2013, 2015, 2018, and 2020 were used in this study to see the change in the temperature and land cover. The study confirmed a significant increase in landfill surface temperature, with the highest value of 67°C found in 2018 and the minimum is 30°C in the year 2006. It also showed that compared to the surrounding area, the landfill has a higher temperature, followed by the built-up area of land cover that expanded from time to time. The accuracy of supervised classification of the land cover in 2006-2020 ranged between 58%-98%, and the Kappa coefficient ranged from 0.42 to 0.97.

1. Introduction

Makassar is one of the big cities in Indonesia, with a population of approximately 1,5 million people in 2019. In 2021, Makassar generated 1,023.71 tons/day, increasing by around 6% from the previous year. However, this increase in waste volume every day is not facilitated by good waste management, especially the final processing in the landfill. Most of Makassar citizens' waste was disposed of in the Tamangapa landfill located in the eastern part of Makassar, which still uses the open dumping method in the landfill operation [1]. The waste characteristics disposed of in Makassar city were dominated by organic waste sources from food scraps and leaves. Based on data from the Indonesia National Waste Management Information System [2], in 2020, the composition of organic waste from food waste in Makassar was 58.42%, the highest compared to other types of waste, followed by plastic. This high composition of organic waste in landfill has the potential to produce a high rate of greenhouse gas (GHG) emissions and heat [3,4], especially for landfill which poorly managed and has non-functioned facilities, as in the Tamangapa landfill [5,6].

Land surface temperature, typically described as the surface temperature of the Earth, one of the many land surface characteristics, is crucial in regulating the majority of the Earth system's physical, chemical, and biological processes [7]. A landfill site is one of the vital areas in which the surface temperature needs to be monitored to evaluate the landfill's effects on the environment and prevent fires in landfill [4]. However, obtaining Landfill surface temperature data through ground measurements at landfill sites requires a high cost for devices and the expert. Direct monitoring of landfill also has difficulties in determining the measurement point, instrument position, and analysis [8]. Therefore, using another method, such as remote sensing data generated from satellite images, is a feasible and effective alternative to monitoring the landfill surface temperature [4].

Several studies on mapping and monitoring a landfill's surface temperature with the surrounding area have already been reported. For instance, the Al-Qurain in Kuwait reported that the surface of the landfill site had a higher temperature than the nearby desert using Landsat Thematic Mapper (TM) [4]. Also, a study was conducted in two Vietnam landfills (Nam Son and Da Phuoc landfill) using Landsat 8 data [9]. These studies show that landfill sites may be identified and mapped using satellite-based remote sensing technologies that employ time series analysis and suitable image processing methods based on variations between baseline surface temperatures and their surroundings [10]. However, there is no study found to investigate the land surface temperature in Makassar landfill.

Furthermore, the land surface temperature can also be compared with land cover since the research on land cover classification methods based on Landsat images has been an important topic over decades, especially with the current effects of climate change [11]. Regarding all the reasons above, this study aimed to map the landfill surface temperature and the surrounding area, then correlate it to the land cover change.

2. Methodology

2.1. Study location

This study is located in Makassar, Tamangapa Landfill, and the area surrounding with a radius <2.9 km to cover different types of land cover. The landfill is situated at coordinates 5,17520 S; 119,49350 E. This landfill is open dumping and has been in service since 1993 with an area of 14.3 hectares. However, there is an extension of land for numerous zones as a result of the rising amount of waste in Makassar. As a result, the Tamangapa landfill area expanded to 16.8 hectares in 2015 [5,6]. There is no daily cover dirt, and the waste reported has reached a height of 20 meters [6].

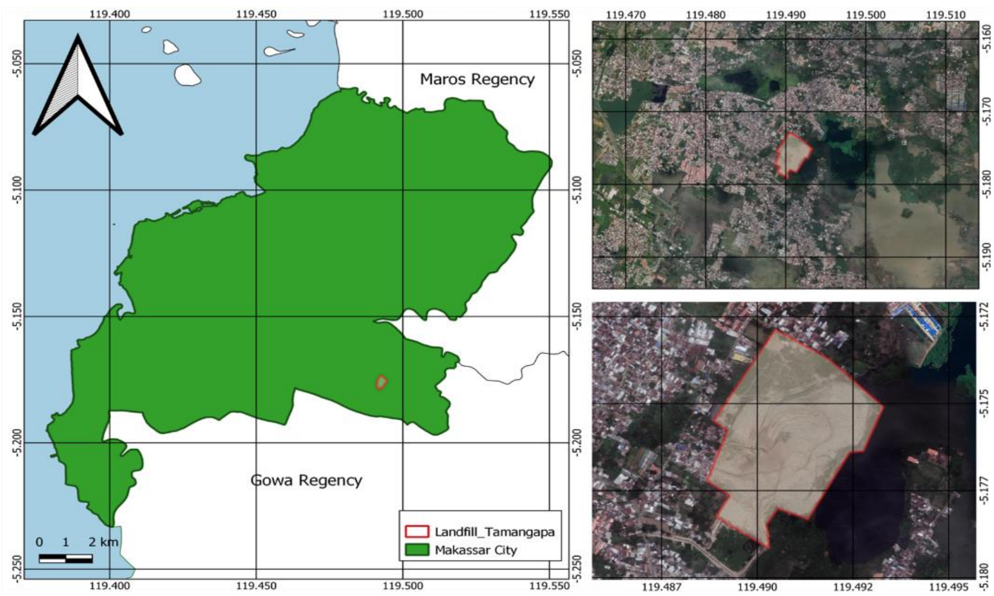

Figure 1. Location and an aerial view of Tamangapa Landfill and its surrounding in this study

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2.2. Data collection and image processing

The data collected in this study were satellite data and solid waste amount in landfill collected from Makassar Environmental Agency. The Landsat Collection 2 Level 2 satellite images of the study location (GeoTIFF format) were downloaded from the U.S. Geological Survey (USGS) Earth Explorer online archive (https://earthexplorer.usgs.gov). The Landsat satellite data were used to detect the land surface temperature of the landfill and the area surrounding it and for land cover analysis. All relevant data was generated in the dry season (April – September) between 2006 – 2009 (Landsat 5) and 2013 – 2020 (Landsat 8) with less than 10% overall cloud coverage. In addition, the SRTM DEM data was also collected to map the elevation contour. Detailed information about data acquired in this study is provided in Table 1.

Table 1. Data collection information

Data	Data acquired	Spatial Resolution (m)	Cloud cover (%)
Landsat 5 TM C2 L2	July 13th, 2006	30 m	< 10%
Landsat 5 TM C2 L2	July 5th, 2009	30 m	< 10%
Landsat 8 OLI/TIRS C2 L2	April 27th, 2013	30 m	< 10%
Landsat 8 OLI/TIRS C2 L2	Sept 8th, 2015	30 m	< 10%
Landsat 8 OLI/TIRS C2 L2	Sept 16th, 2018	30 m	< 10%
Landsat 8 OLI/TIRS C2 L2	Aug20th, 2020	30 m	< 10%
SRTM 1 Arc-Second Global	Sept 23rd, 2014		

The data was then processed using QGIS 3.22.6. For the land surface temperature processing, the data in Landsat 5 uses band 6, and Landsat 8 uses band 10. The data is already in Kelvin, which scale factor provided in metadata has to be applied by pre-processing step using equation 1 [12] in raster calculation.

$$ST = 0.00341802\ (DN) + 149.0 \tag{1}$$

DN is the digital number, 0.00341892 is the scaling factor for the Surface Temperature Data in the Landsat image, and 149 is the offsite value [12]. After applying the scale factor, the data in the Kelvin unit will be converted to Celcius by minus 273.15.

The methods of land cover classification to be applied to Landsat images were visual analyses starting from 2006 to 2020, followed by supervised pixel-based classification methods using maximum likelihood in the Semi-Automatic Classification Plugin of QGIS. Supervised classification is the method of taking a sample of pixels from the image and utilizing them to set thresholds to distinguish different types of ground cover. Hence, it requires prior knowledge of land cover types before classification [11]. To meet the requirement, this study uses Google Earth Pro historical images to help classify the land cover type and the technical guidelines for interpreting medium-resolution satellite images provided by the Ministry of Environment and Forestry Indonesia [13]. The classification class used in this study were Building and housing, vegetation, paddy field (wet), agriculture (dry), water bodies, landfill, and open area. The assessment for the classification accuracy in the land cover analysis was also performed in this study using the accuracy tool in Semi-Automatic Classification in QGIS. The flowchart of this study methodology showed in Figure 2.

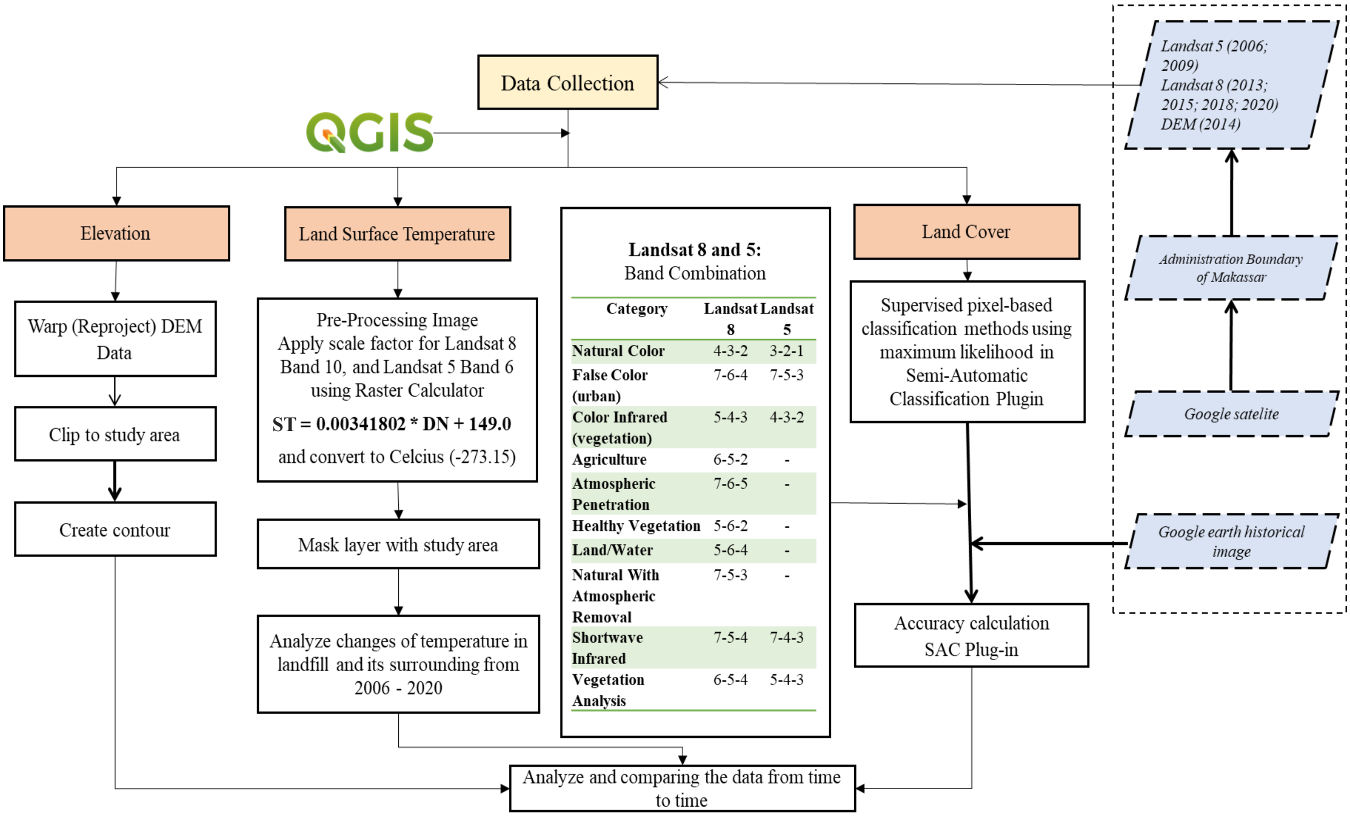

Figure 2. Data collection and image processing methodology flowchart

3. Results and Discussion

3.1. Waste data and landfill change

The waste data in the Tamangapa landfill was acquired directly from the Makassar Environmental Agency in the year used for this study, shown in Figure 3.

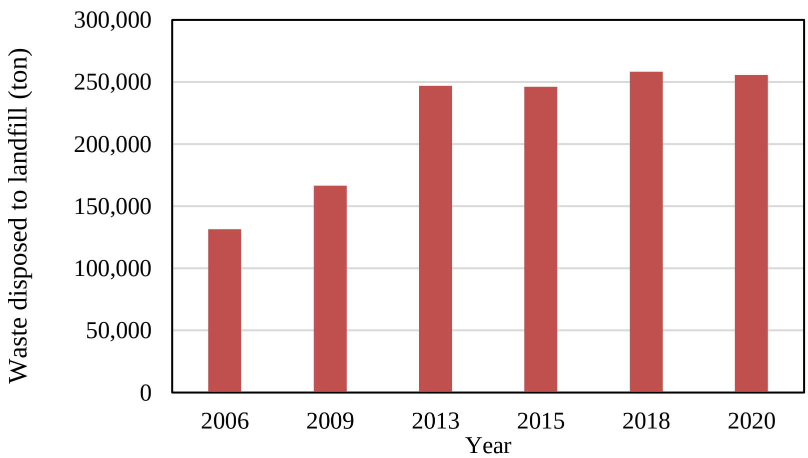

Figure 3. The annual amount of waste generated in landfill from 2006-2020

The waste disposed to the Tamangapa landfill in Makassar has an increasing trend from 2006 to 2020. As can be seen, the highest waste amount generated is in the year 2018. The amount generated in the landfill was increased then decreased but not too significant until 2020. Figure 4 illustrates the visual landscape change of landfill depicted on Google Earth.

Figure 4. The landscape of Tamangapa Landfill Makassar 2006-2020

In Figure 4, the Tamangapa landfill has changed due to the amount of disposed waste in the landfill as well as the land cover in the landfill site. The area of the landfill becomes larger than its capacity resulting in the land addition for the landfill site.

3.2. Landfill Surface Temperature

The landfill surface temperature is one of the important parameters in landfill monitoring. The estimation of the landfill surface temperature in Tamangapa Landfill, Makassar, was determined using Landsat 5 and 8. The result is provided in Figure 5. Comparing each year's results showed a significant increase in landfill surface temperature from 2006 to 2018. However, the temperature declined from the year 2018 to 2020. The temperature increases with the highest temperature found in 2018 at 67°C, whereas the lowest was found in 2006 at 30°C.

The landfill surface temperature can be influenced by several factors. According to Qdais [4], the amount of solid waste in landfill has resulted in a good correlation with landfill surface temperature due to the waste generation that keeps increasing from time to time. This is to be expected since when more waste is disposed of in landfills, more organic materials will be subjected to exothermic biodegradation reactions, which are often linked to heat and methane production. The heat generated in landfills is the by-product of the biological decomposition of organic waste along with leachate and gas [3,10]. As in Figure 3, which has already been discussed, the amount of waste disposed of in the Tamangapa landfill generally has an increasing trend from year to year. As reported in Santoso [5], in 2014, the composition of organic waste in the Tamangapa landfill was 70.43%.

Furthermore, Based on Lando et al. [6], in 2015, there was an additional 2 hectares of landfill. Therefore, as stated in Qdais et al. [4], the change in the land cover of landfill (Figure 4) is one of the reasons for a temperature difference, as shown in Figures 5c and 5d. In 2015 the temperature became higher than in previous years since the zone that was previously not used to dump the waste was used. Meanwhile, Figure 5e shows the highest temperature of the landfill surface.

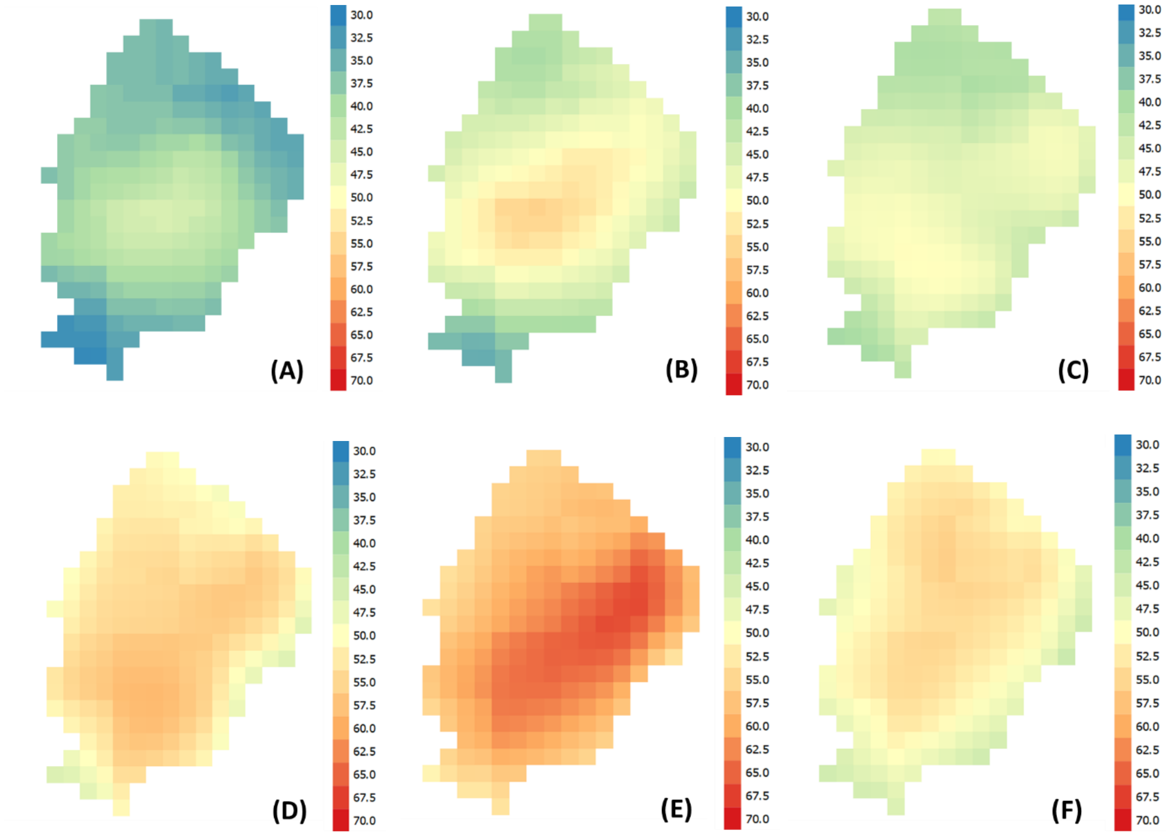

Figure 5. Tamangapa Landfill surface temperature (Celcius) in (a) July 13th 2006 (b) July 5th 2009 (c) April 27th 2013 (d) September 8th 2015 (e) September 16th 2018 (f) August 20th 2020

In 2018, the landfill surface temperature ranged from 51-67°C. It indicated that due to the high amount of waste disposed of and accumulated from the previous years, according to data from Makassar Environmental Agency, in 2017, the waste generated reached 290,222 tons higher than years before. Moreover, surface temperature variations are also influenced by a variety of factors, such as weather conditions, for instance, sun radiation, humidity, and so on [14]. Thus, it is also indicated that the high landfill temperature was probably influenced by the meteorological condition in 2018. The Landsat data used in this study for the year 2018 was also acquired before the landfill fire due to the hot climate in October [15]. However, in this study, meteorological data was not collected. Hence, an in-depth discussion regarding the meteorological aspect and landfill surface temperature needs to be investigated for the next study. It also needs to be highlighted that the estimation using remote sensing data only provides a general estimation for the intensity of the waste decomposition process at a largescale level in the landfill [8]. Direct measurement in the same atmospheric conditions as the landfill itself is also required to validate the result of satellite data [8]. Hence, further research is needed.

3.3. Land Surface Temperature Surrounded Landfill

In order to see the difference in landfill surface temperature to the area surrounding the landfill, the land surface temperature of the area nearby was investigated. The land surface temperature was obtained from Landsat data and layered with the elevation data depicted in Figure 6.

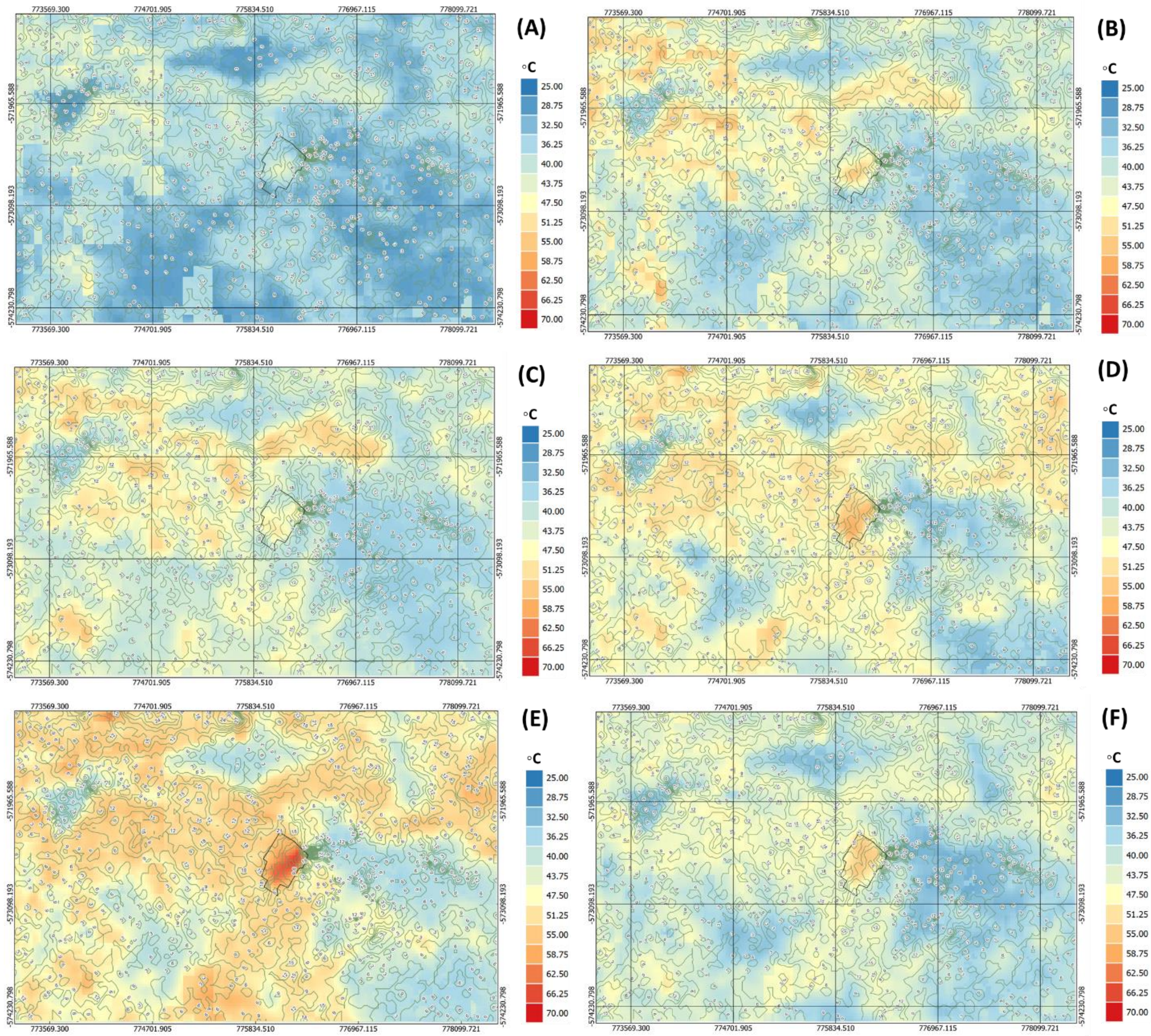

Figure 6. Land surface temperature (Celcius) surrounding landfill in (a) July 13th 2006 (b) July 5th 2009 (c) April 27th 2013 (d) September 8th 2015 (e) September 16th 2018 (f) August 20th 2020

In Figure 6, the surface temperature increased from 2006 to 2018 and then decreased in 2020, similar to the trend of landfill surface temperature data in Figure 5. Based on the result, it shows that the landfill body has a higher temperature than its surroundings ranging from around 1-19°C temperature difference, implying there is an activity in the landfill that can produce heat. The same phenomena also occurred in Nam Son landfill and Da Phuoc landfill in Vietnam, where the landfill surface temperature was so much higher than the surrounding area [9]. It is assumed that it is due to the presence of a biodegradation process inside the landfill body related to gas emissions through the surface of the landfill, as also reported in Qdais et al. [4]. Moreover, as mentioned in Zhang et al. [14], the difference in surface temperature is affected by factors including land cover.

3.4. Land cover change

The result of land cover classification using supervised classification for the area surrounding the landfill from 2006 to 2020 is illustrated in Figure 7.

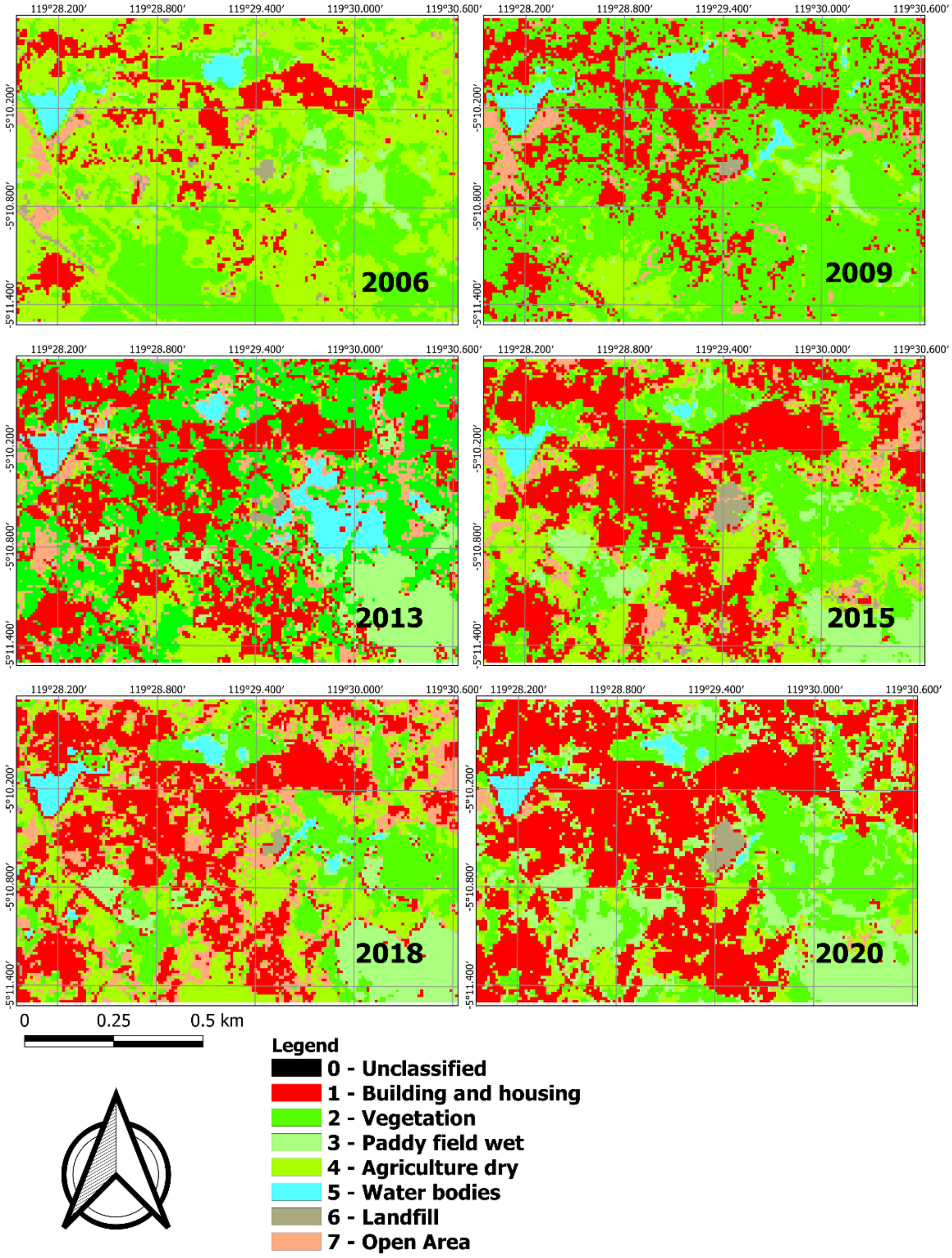

Figure 7. Land cover surrounding landfill in (a) July 13th 2006 (b) July 5th 2009 (c) April 27th 2013 (d) September 8th 2015 (e) September 16th 2018 (f) August 20th 2020

The result in Figure 7 presented that there is a change detected in land cover type for each classification category. The percentage of the land cover area for each category is presented in Table 2. According to Table 2, the majority of the land cover category is the building and housing (built-up) category which tends to expand from 2006 to 2020 due to activity and population increase. Whereas the vegetation area increased until 2009 and then declined. The same result was also found in Saputro et al. [16], who investigated changing land cover areas in Makassar increasing in 1999, 2010, and 2015.

Table 2. The land cover percentage for 2006 - 2020

Category	Percentage (%)					
	2006	**2009**	**2013**	**2015**	**2018**	**2020**
Building and Housing	9.53	23.02	30.02	35.00	31.06	42.93
Vegetation	29.28	60.55	35.42	22.76	17.77	18.23
Paddy field (wet)	3.31	1.38	10.23	8.55	9.84	22.80
Agriculture (dry)	52.99	6.75	9.16	22.84	23.06	12.04
Water bodies	1.64	2.64	4.92	1.12	2.23	1.71
Landfill	1.48	0.63	1.85	2.09	0.56	1.03
Open area	1.76	5.03	8.38	7.63	15.48	1.26

Based on Table 2, the landfill area percentage was having fluctuation and had a different pattern from its visual change in Figure 4. This is because of the limitation of the method used and the need for field data for better results. Compared to the land surface temperature in Figure 6, the higher temperature was in the built-up area and the landfill. As mentioned in do Nascimento [17], the relationship between the land surface temperature and land cover classification is the temperature will be higher in regions with higher densities of people, followed by lower densities area and vegetation cover, then high vegetation densities area and water bodies have lower temperatures which are similar to the result of this study. Furthermore, the classified image in land cover identification needs to be assessed for accuracy to evaluate the accuracy with which the pixels were sampled into the appropriate land cover classes on a quantitative level so that it can be used as input for any applications or further study [18]. The land cover accuracy of this study was calculated directly in the QGIS presented in Table 3.

Table 3. Land cover accuracy for 2006 - 2020

Year	Overall accuracy (%)	Kappa coefficient
2006	98.09	0.970
2009	61.51	0.496
2013	97.3	0.965
2015	90.66	0.877
2018	58.09	0.424
2020	94.08	0.918

The overall accuracy in Table 3 ranged between 58% - 98% and the Kappa coefficient ranged from 0.42 to 0.97. The Kappa coefficient of or near 1 is in perfect agreement, whereas a number near zero indicates that the agreement is poor [18]. Based on the rating criteria of Kappa statistics [18], the land cover classification of 2006, 2013, 2015, and 2020 are in almost perfect agreement. It also has high accuracy with a value above 90%, where overall accuracy of 85% is widely used as a minimum for acceptable results [19]. Hence, the approach of supervised classification is acceptable and well suited for classifying the land covers in Landsat 5 and 8 data. Meanwhile, the 2009 and 2018 data have an overall accuracy percentage lower than 85%, thus, affecting the result of the land cover classification. The low accuracy indicates confusion during the land cover classification process since the method used is a supervised classification that requires prior knowledge and primary field survey data to classify the land cover type. However, the Kappa coefficient is still in the moderate category according to Rwanga and Ndambuki [18].

4. Conclusion and Recommendation

The study confirmed that the land surface temperature and the area surrounding the landfill increased from 2006 until 2018. It declined in 2020 which was influenced by the amount of waste generated and other factors. The minimum landfill surface temperature was found in 2006 at 30°C, and the highest was in 2018 at 67°C. The study also found that there is a correlation between land surface temperature and land cover change, where the highest temperature comes from the landfill and built-up areas. The accuracy of supervised classification of the land cover is ranged between 58% - 98%, and the kappa coefficient is ranged from 0.42 to 0.97. As a recommendation, further validation is needed through primary observation and measurement in the field.

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