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USING DRONES FOR LANDFILL MONITORING AND PROJECTION CALCULATION

Yackob Astor*, Aditia Febriansya*, Retno Utami*, Muhammad Rizki Firdaus*, Farhan Arradzumar Gustaman*, and Saepul Fariz*

*) Civil Engineering Department, Politeknik Negeri Bandung, Indonesia

Corresponding Author: yackobastor@polban.ac.id

ABSTRACT

Until now, monitoring the landfill volume in the Sarimukti landfills is calculated by the ratio of trucks converted from tonnage to volume based on the density of the landfill. The various truck specifications and the landfill density conversion process affect the tonnage value. This has an impact on the accuracy of the landfill volume calculation results. This research uses drones as the main tool for monitoring Sarimukti landfills by making a 3D map of the landfill in 2021 as a reference for calculating the volume of existing landfill. The analysis was carried out by comparing the existing landfill volume with the projected landfill volume in 2025 according to the operational period of the landfills. The results of the analysis show that the Sarimukti landfills can no longer accommodate landfill by 2023.

Keyword: *Drone, Landfill, Contour*.

I. INTRODUCTION

The landslide tragedy at the Leuwigajah landfills on the 21st of February 2005 was one of the biggest humanitarian disasters caused by landfill. 157 people died and two villages in an area of 26 hectares were buried by landslides of landfill up to 3m high. This disaster occurred because the landfill collected in the Leuwigajah landfills had exceeded its capacity. This tragedy is commemorated as National Landfill Day (Fig.1).

Figure 1. Landslide Tragedy at Leuwigajah Landfills, West Java Province (F, Lavigne at al, 2014)

The result of research conducted by F Lavigne et al The result of research conducted by F Lavigne et al stated that 2.7×106 m3 of waste materials spread 1000 m from the source in a rice field with an average thickness of 10 m. The material displays a preferential fabric parallel to the previous topography. Numerous internal slip surfaces, underlined by plastic bags explain the low friction coefficient. The presence of methane within the waste dump was responsible for explosions prior to sliding and for the fire that affects whole sliding mass. Resulting of a combination of heavy rainfall and consecutive explosions due to biogas sudden release, this disaster was predictable in reason of (1) a front slope of the dump of about 100% before the failure; (2) a poor dumpsite management; (3) the extreme vulnerability of the marginalized scavengers living at risk at the foot of the instable dump. (Lavigne et al. 2014).

Since then, landfill from Bandung City, Cimahi City, Bandung Regency, and Bandung Barat Regency has been accommodated in Sarimukti landfills that cover an area of 25 ha in Sarimukti Village, Cipatat District, Bandung Barat Regency. This land was originally as a forest. Currently, Sarimukti landfills has undergone 2 extensions of its service period in 2017 for 3 years and in 2020 for 5 years (Fig.2). The main landfill management scheme at these landfills is controlled landfill which is a method of piling up landfill by compacting and backfilling it with soil using excavators and dozers. In addition, Sarimukti landfills also manages landfill by composting for organic landfill and recycling by scavengers.

Figure 2. Sarimukti Landfills (Google Earth)

Up until now, the landfill volume calculation has been done by calculating the ratio trucks converted from tonnage to volume based on the density of the landfill. The calculations are carried out manually and continuously every day. This routine activity has the potential to cause human and tool error. Some causes or errors are various truck specifications and the landfill density conversion process which affect the tonnage value and the accuracy of the landfill volume calculation results. A comprehensive monitoring method is required to calculate the landfill volume accumulatively and to visualise the height and slope of existing and future landfill.

Unmanned Aerial Vehicles (UAVs) or generally called drones are aerial photogrammetry technology used as a tool for measuring, mapping, calculating, as well as supervising. The advantage of mapping using drones lies in the ability to fly at an altitude close to the object, so it can photograph real-time objects in the field excellently to produce large-scale map products in 2D and 3D. Drones have been widely applied for civilian needs.

During the times of a public health emergency, such as the COVID-19 pandemic, an UAVs or drones, can offer many advantages. They can not only ensure minimised human interaction, but it can also reach inaccessible areas. China, the first country to face the wrath of the COVID-19, has made great use of drone technology to counter the COVID-19 outbreak. Taking that as inspiration, several countries around the world have joined forces with numerous researchers and innovators in an attempt to find ingenious ways of using drones to fight COVID-19 (Chamola et al. 2020). In the tourism industry, UAVs can perform monitoring and patrol missions to protect assets and tourists at attractions in coastal areas, canyons, national parks, etc. The use of UAVs can improve the safety and security of tourism attractions and facilitate the tourism industry (Ko dan Song 2021).

In the field of construction, drones are used as a routine inspection tool to check the age and damage to structures such as bridges or buildings. Visual inspection using drones has many advantages such as speed, safety for workers, cost-effectiveness, the ability to share with more stakeholders instantly, and the ability to manoeuvre using automatic flight (Ciampa, De Vito, dan Pecce 2019). The bird eye-view angle of the camera provided by the UAVs is importantly considered as it allows the extraction of vehicle trajectories with more accuracy in lateral distances, which significantly helps improvement in the traditional methodologies and models used in traffic analysis (Outay, Mengash, dan Adnan 2020).

The scientific application of UAVs in mining areas has mainly focused on surface measurements, such as 3D reconstruction, terrain surveying, landslide stability analysis, and air pollution monitoring (Ren et al. 2019). The use of drones for mining areas has several similarities with this research. The main difference lies in the activities of the dynamic landfill area and open access. Every day, several trucks enter and leave the landfills, including local people who live in the area and work as scavengers (see Fig.3). This condition is different from mining areas that have limited access. Landfill monitoring is an imperative effort to prevent landslide disasters such as the one that occurred at the Leuwigajah landfills (Hendra 2016).

Figure 3. Landfills Access is Open to The Local People

II. LITERATURE REVIEW

All landfill management systems in Indonesia were originally designed with a sanitary landfill system (Landfill Management Law Republik Indonesia 2008). However, in its implementation almost all landfills are currently operated by open dumping (Hendra 2016; Kementrian Pekerjaan Umum 2009). This is because the construction and management of a sanitary landfill system requires a large amount of money. The high operational costs are influenced by the procurement of heavy equipment, the provision of land cover, operation and maintenance, and the provision of trained personnel in managing the sanitary landfill. In addition, the application of the sanitary landfill system also requires a large area of land that meets certain technical requirements. Meanwhile, the amount of landfill in Indonesia continues to increase along with the population growth and with the improving welfare level. Indonesia is ranked second as the largest contributor of plastic waste to the oceans in the world with 187.2 million tons, just below China which is ranked first with 262.9 million tons (Jambeck et al. 2015).

The Ministry of Environment and Forestry stated that the national amount of landfill is increasing 175,000 tons per day, or it is equivalent of 64 million tons per year using the assumption that 0.7 kg of landfill is produced per person per day. In 2020, the amount of landfill in Indonesia will have reached 67.8 million tons (Baqiroh 2019).

2.1 Regulation of Landfill Management in Indonesia

The management of landfill infrastructure and facilities in handling household and household-like landfill is regulated by Minister of Public Works of the Republic of Indonesia in the ministerial on conducting, facilitating, and handling household waste and household-like waste (Menteri Pekerjaan Umum 2013). The following are some of the provisions related to landfill:

(1) On top of the landfill in the form of lift is filled with new landfill, forming height (as described in Figure 4). If the landfill is made using the area method, the boundary between the 2 lifts is 3-5 m wide terracing to strengthen the stability of the landfill (Menteri Pekerjaan Umum 2013).

The provisions are illustrated in Fig.4 which shows that the landfill thickness per layer is 5 m, the slope is 1:3, and the inter-slope offset is 5 m.

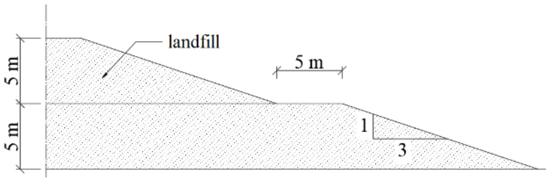


Figure 4. Provisions for Landfill

(2) The stability of landfill slope at the existing landfill must be maintained by improving the slope and maintaining the integrity of the cover soil.

(3) Compaction of landfill is carried out using heavy equipment to achieve a minimum landfill density of 600 kg/m3 with a maximum slope of 30˚.

Whereas for the landfill calculation and projection, the Regulation of the Minister of Public Works of the Republic of Indonesia Number 03/PRT/M/2013 in the sub-chapter of the Survey and Assessment of Sources of Landfill Arising stated the composition and characteristic of landfill, intended to acquire a basis for planning the needs for landfill infrastructure and facilities in the short, medium and long term. Estimation or projection of landfill is obtained after the existing data is known. The method of taking and measuring samples of the landfill arising and composition of municipal solid landfill is regulated in SNI No.19-3954-1994 (Badan Standarisasi Nasional 1994). Landfill arising is the multiplication of the landfill coefficient and the population in a city. The landfill coefficient is influenced by the size of the city, which is 0.4-0.5 kg/person/day for large cities and 0.3-0.4 kg/person/day for medium and small cities. A large city is defined to have a population of 1-2.5 million people, a medium city has a population of 0.5-1 million people, and a small city has a population of 0.3-0.5 million people (SNI 19-3964-1994 1994).

2.2 Volume Calculation Using a Drone

Volume calculation based on images taken by a drone is done mathematically using coordinates (XYZ), with which the X and Y coordinates will form a polygon, while Z provides information on the height of the polygon. There are three base-plane options available for volume calculation; Linear Fit, Lowest Point and Triangulated (dronedeploy.com n.d.).

- Linear Fit (formerly “Best Fit”) defines the base plane by fitting a perfectly flat plane, in 3D, through the chosen edge points. It is considerable for stand-alone stockpiles in most situations on flat ground.

- Lowest Point calculates a horizontal base plane from the lowest edge point. This option is more suited to calculate the volume of benches or stockpiles on flat ground in bins, or where there are neighbouring piles right up against each other. The lowest point of the base plane is very sensitive to the vertices of the volume annotation being created and assumes the ground under the annotation is very flat. If the ground is slightly sloped, this can distort the results.

- Triangulated joins up all the edge points to create a 3D surface under a stockpile. This is perfect for long thin stockpiles or for large stockpiles of over 0.5 acres in size.

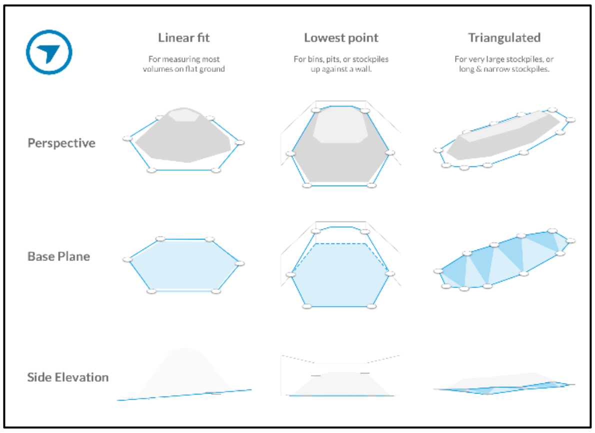


Figure 5. Comparison of Volume Calculation Methods (dronedeploy.com)

Figure 5 visualises the characteristics of the object and the method of calculating the appropriate volume according to the characteristics of the object. Briefly, the volume calculation of the Lowest Point method is more appropriate in this research. However, the Linear Fit method can also be used because the piles of landfill in the field have different side elevations. Likewise, the Triangulated method is suitable for landfill piles that spread wide and elongated. This research did not compare the volume values using the 3 methods above.

The volume calculation in this research was carried out using a comparison of the contours (ground surface) in the landfills area in 2017 with the contour of the results of the drone visualising data process in 2021. In the introduction, it was mentioned that the Sarimukti landfills has been operating since 2006 until now and has experienced 2 extensions of its service period, specifically in 2017 for 3 years and in 2020 for 5 years. By using the 2017 data, this research finds out whether the Sarimukti landfills is able to operate until 2025 or will it be overfilled. This information is very important as an effort to prevent landslide disasters such as at the Leuwigajah landfills in 2005.

Based on the introduction and literature review, this research is very important related to monitoring the volume of waste periodically and being able to produce information in a fast time. Therefore, drone technology is very appropriate to be implemented to prevent the occurrence of waste landslide disasters by taking photos per week or after rain, then build 3D model to calculate the slope of the waste pile and the volume of the existing waste. The data are used as basis for making decision and policies.

III. METHODOLOGY

The following is a flow chart of research methodology, starting from the preparation stage, data acquisition, process, output, to analysis.

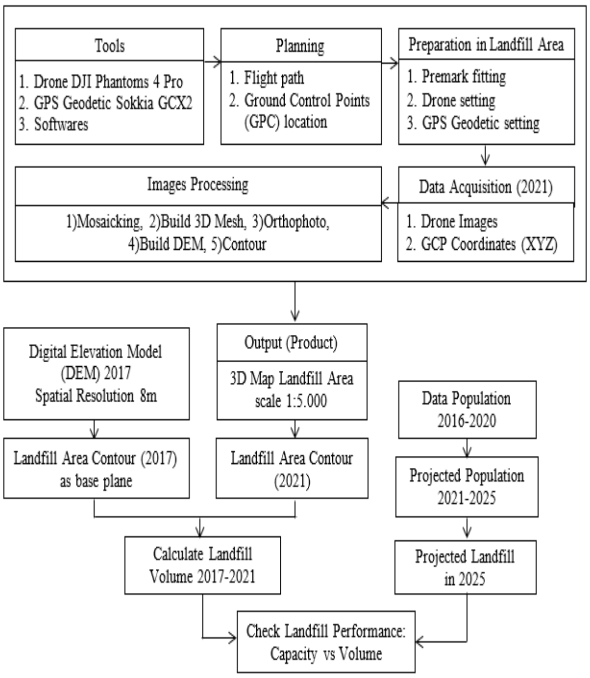


Figure 6. Research Methodology

The tools used were the DJI Phantom 4 Pro Drone, Sokkia GCX2 GPS Geodetic, and certain software such as Ctrl PLUS DJI, Pix4d Capture, Agisoft Metashape Professional, ContextCapture, Global Mapper, and Civil 3D. The number and distribution of Ground Control Points (GCP) were planned based on the area and shape of the landfills. Preparation in the field included the installation of pre-mark GCP, drone settings, and GPS Geodetic settings. There were 7 GCPs set by a GPS observation survey in the location of landfill area. The visualisation was carried out at height of 60 m using an overlap of 55%, sidelap of 55%, and an upright camera position of 90˚. After that, GPS observation survey and photo taking were carried out in January 2021 and 918 photos and 7 GCP coordinates were obtained (Fig 7).

Figure 7. Drone Survey and GPS Observation in Sarimukti Landfills

Data processing began with the Align process, which is displaying, and reconstructing photos based on the flight path and the conditions set at the time of visualising, to obtain an overall, sequential, and orderly overlay of the photos. Furthermore, the 3D Mesh Build process was carried out to display a 3D model visualisation based on the overall photo and actual topographic conditions in the field. 3D Mesh is a structural arrangement of a three-dimensional model consisting of polygons using reference points in the X, Y, and Z axes to define a shape with height, width, and elevation (Fig.8). For the 3D model to have high accuracy, GCP input was carried out on the model, thus it had a high degree of accuracy (error ≤ 0.5 m).

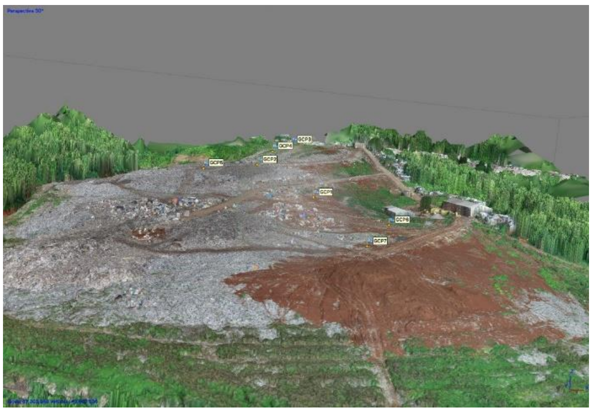
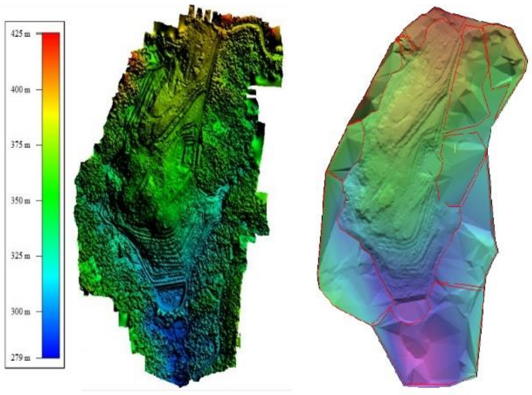


Figure 8. 3D Mesh

For ground-level model, some references use the term Digital Elevation Model (DEM). However, other references have begun to classify DEMs into Digital Surface Model (DSM) and Digital Terrain Model (DTM). DSM includes information on the height of objects above the ground such as trees, rice fields, buildings, and other objects in the visualising area. In contrast, DTM only displays ground level. In this research, the data needed was DTM because landfill management at Sarimukti landfills use controlled landfill, a method of piling up landfill by compacting and backfilling it with soil using excavators and dozers. Landfill is piled up with soil every 5 meters and then covered with soil of 30-50 cm thick. The results of DTM drone capture in 2021 were representative of the landfill pile since 2006.

In Fig 9a, the DSM of Sarimukti landfills shows the shape of the land surface and the objects above it such as trees and buildings, displayed using colours indicating different ground levels. Whereas in Fig 9b, the DTM of Sarimukti landfills only shows the shape and height of the land surface excluding trees and other objects.



(a) (b)

Figure 9. DSM (a) and DTM (b)

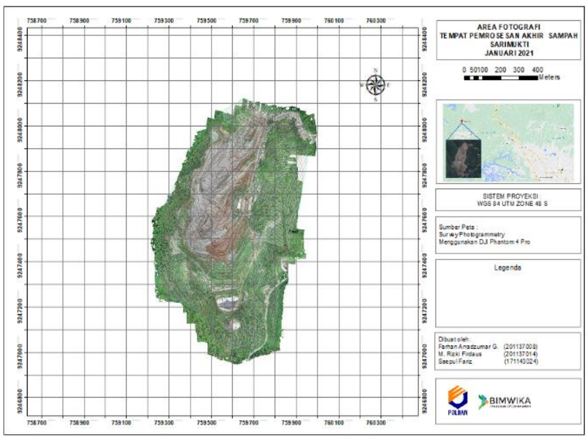


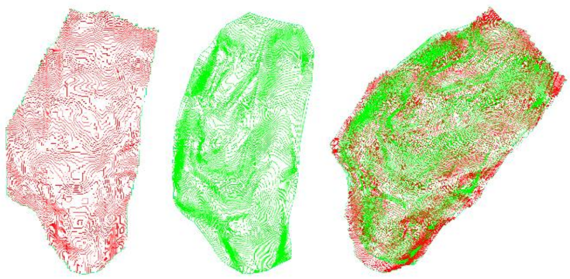
Figure 10. Sarimukti Landfills 3D Map

Furthermre, the orthophoto process was carried out by making a series of vertical/upright aerial photographs into one unit which were corrected geometrically so that the scale and orientation of the photo were uniform. One of this research outputs is the 3D map of Sarimukti landfills, which displays a 3D visualisation of the land and landfill surface in the area, equipped with contours and other supporting information such as the location of entrances and exits, heavy equipment workshops, and leachate treatment (Fig.10).

IV. RESULT AND DISCUSSION

4.1. Analysis of Existing Landfill Volume Until 2021

Existing landfill volume was obtained by comparing the contours of the landfill area in 2017 and 2021. The contours of the landfill area in 2017 (Fig.11a) were obtained from the 2017 DEM which had a spatial resolution of 8 m, then converted (raster to vector) in the form of contours. Meanwhile, the contours from 2021 were obtained from the DEM drone capture that were classified as DTM and converted into a vector (Fig.11b). Furthermore, the contours were overlaid from 2017 to 2021, so the difference in land surface elevation in the landfills area was seen (Fig.11c).



(a) (b) (c)

Figure 11. Contour 2017 (a), Countour 2021 (b), Overlay Contour 2017 and 2021 (c)

A comparison of the soil surface was carried out in the landfills area to determine the volume difference between the contours of 2017 and 2021. For this reason, sample lines and cross-sections were made in the landfill area (Fig.12a). The existing landfill volume was calculated from the difference area (shaded) multiplied by the distance between the pieces, which was 20 m (Fig.12b and 12c). The results of the existing landfill volume calculation in 2021 are presented in Table 1.

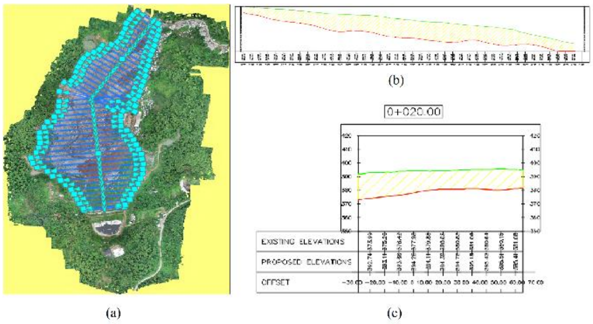


Figure 12. Calculation of Area and Volume on Orthophoto (a), Long Section (b), Cross Section (c)

Table 1. Landfill Volume Based on Contour Comparison of 2017 and 2021

Station	Landfill Area (m^2)	Landfill Volume (m^3)	Landfill Volume Cumulative (m^3)
0+000.00	1,140.24	-	-
0+020.00	1,759.04	28,992.80	28,992.80
0+040.00	2,177.90	39,369.41	68,362.21
0+060.00	2,601.54	47,794.41	116,156.62
0+080.00	2,794.19	53,957.24	170,113.86
0+100.00	2,866.39	56,605.80	226,719.66
0+120.00	3,042.31	59,087.02	285,806.68
0+140.00	3,358.86	64,011.68	349,818.36
0+160.00	3,878.15	72,370.13	422,188.49
0+180.00	4,303.16	81,813.11	504,001.60
0+200.00	5,209.88	95,130.43	599,132.03
0+220.00	6,313.39	115,232.78	714,364.81
0+240.00	6,869.14	131,825.32	846,190.13
0+260.00	7,049.22	139,183.57	985,373.70
0+280.00	7,287.13	143,363.50	1,128,737.20
0+300.00	7,372.13	146,592.63	1,275,329.83
0+320.00	7,376.11	147,482.46	1,422,812.29
0+340.00	7,712.03	150,881.41	1,573,693.70
0+360.00	7,771.78	154,838.04	1,728,531.74
0+380.00	8,075.62	158,473.95	1,887,005.69
0+400.00	8,172.74	162,483.52	2,049,489.21
0+420.00	8,113.10	162,858.34	2,212,347.55
0+433.33	9,320.20	116,194.88	2,328,542.43
0+440.00	7,606.75	57,403.80	2,385,946.23
0+460.00	8,536.03	161,427.84	2,547,374.07
0+480.00	9,197.49	177,335.20	2,724,709.27
0+500.00	9,692.49	188,899.79	2,913,609.06
0+520.00	10,667.4	203,599.20	3,117,208.26
0+540.00	10,876.1	215,434.90	3,332,643.16
0+560.00	10,794.1	216,701.75	3,549,344.91
0+580.00	10,913.8	217,079.49	3,766,424.40
0+600.00	11,141.7	220,555.49	3,986,979.89
0+620.00	11,390.6	225,323.26	4,212,303.15
0+640.00	10,723.6	221,142.19	4,433,445.34
0+660.00	9,410.14	201,337.50	4,634,782.84
0+680.00	7,962.14	173,722.85	4,808,505.69
0+700.00	6,577.47	145,396.09	4,953,901.78
0+720.00	5,512.93	120,903.96	5,074,805.74
0+740.00	4,735.17	102,481.05	5,177,286.79
0+760.00	4,379.01	91,141.87	5,268,428.66
0+780.00	4,096.93	84,759.40	5,353,188.06
0+800.00	3,304.54	74,014.68	5,427,202.74
0+820.00	2,407.59	57,121.28	5,484,324.02
0+824.04	3,002.99	10,930.33	5,495,254.35

The existing landfill volume based on contour comparison of 2017 and the existing contours of January 2021 was 5,495,254.35 m3. The landfill volume was validated against landfill volume data based on management of trucks obtained from the Sarimukti landfills. Table 2 shows the amount of landfill that entered the Sarimukti landfills based on management data.

Table 2. Incoming Landfill Volume Based on Management Data

Year	Amount of Landfill Per Year	
	m^3	Ton
2017	1,207,972.00	574,994.61
2018	1,463,989.00	680,283.92
2019	1,468,291.00	698,906.69
2020	1.566.800,00	747,288.00
Total	5,707,052.00	2,701,473.00

Source: Sarimukti Landfill Management Data 2020

The landfill volume based on the comparison of two contours was 5,495,254.35 m3; while based on the management data, it was 5.707.052,00 m3. The volume difference is relatively small, which is 211,797.64 m3, so the accuracy of the data is 96.29%.

4.2. Modelling of Sarimukti Landfills Capacity

To obtain the remaining volume that can be accommodated by the Sarimukti landfills, modelling the landfills capacity was carried out based on the maximum height of the stockpile to the existing contours in 2021. Based on the contours of the results from data processing and field surveys, the highest elevation of the land surface at Sarimukti landfills is 398 m. Furthermore, from this highest elevation information, the terracing is made with a slope of 1:3 and 5 m in accordance with the Regulation of Ministry of Public Works year 2013 (illustration can be seen in Fig.4).

After being modelled, the volume was calculated to reach the maximum capacity obtained from the soil surface/existing landfill in 2021 to the highest elevation in the landfill area, which is 398 m (Fig.12). The remaining volume to reach the maximum capacity is 4,634,733.64 m^3.

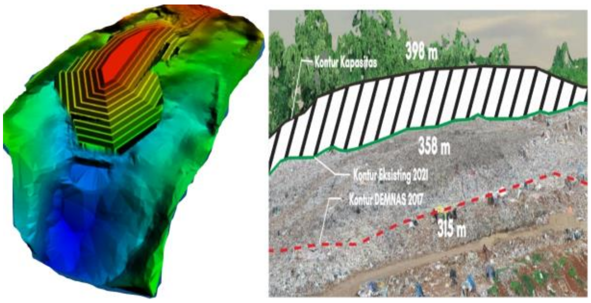


Figure 13. Sarimukti Landfills Capacity Model

4.2. Analysis of the Landfill Arising Projection Until 2025

To analyse the landfill arising until 2025, it was necessary to project the number of populations whose landfill will be accommodated at the Sarimukti Landfills. The population projection was calculated based on population data for the last 5 years obtained from the Central Bureau of Statistics of West Java, Bandung City, Bandung Regency, West Bandung Regency, and Cimahi City. Table 3 presents the population data from 2016 to 2020 and the difference in the average for each region.

Table 3. Population Data Year 2016 – 2020

Year	Total Population (Person)			
	BC	BR	WBR	CC
2016	2,397,2	3,596,6	-	594,02
2017	2,412,4	3,657,7	-	601,09
2018	2,480,4	3,717,2	-	607,81
2019	2,490,3	3,775,2	1,667,7	614,30
2020	2,510,1	3,831,5	1,714,9	620,39
Populati-on Growth Rate	28,202	58,721	23,629	6,593

BC=Bandung City; BR=Bandung Regency; WBR=West Bandung Regency; CC= Cimahi City
Source: Central Bureau of Statistics for West Java, Bandung City, Cimahi City, Bandung Regency, and West Bandung Regency 2021

5.3.1. Calculating the population projection

The population projection for each year was based on the average population increase in each year. The population projection for each year was calculated using the following eq. [1].

$$Un = a + b(n-1) \qquad [1]$$

Where:
Un = Total population in the n year
a = Total population in 2020
b = The average population increase in each year

Bandung City : 28,202 persons
Bandung Regency : 58,701 persons
West Bandung Regency : 23,629 persons
Cimahi City : 6,593 persons

5.3.2. Calculating the landfill arising coefficient

The annual population data for each region was multiplied by the landfill arising for each region. The coefficient of arising refers to SNI 19-3964-1994. Each person is assumed to produce landfill with a coefficient that is influenced by the classification of cities (Metropolitan, Large, Medium, and Small). The arising coefficient for each region is:

Bandung City : 0.45 kg/person/day,
Bandung Regency : 0.45 kg/person/day,
West Bandung Regency : 0.4 kg/person/day,
Cimahi City : 0.3 kg/person/day.

The coefficient value from this calculation may be smaller than the actual conditions at the time.

5.3.3. Calculating the landfill amount that enters landfills per year

The landfill that enters Sarimukti landfills per year was calculated using the following eq. [2].

$$IL = \frac{K \text{ x Total Population x } 365}{1000} \qquad [2]$$

Where:

IL = Incoming Landfill per Year (Ton)
K = The coefficient of landfill arising
Bandung City : 0,45 kg/person/day
Bandung Regency : 0.45 kg/person/day
West Bandung Regency : 0.4 kg/persons/day
Cimahi City : 0.4 kg/persons/day
The following table shows the analysis results of population projection and landfill arising.

Table 1. Population Projection 2021-2025 in 4 Cities/ Regencies

Year	Total Population (Person)			
	BC	BR	WBR	CC
2021	2,538,305	3,890,226	1,738,611	626,986
2022	2,566,507	3,948,946	1,762,240	633,578
2023	2,594,708	4,007,667	1,785,869	640,171
2024	2,622,910	4,066,387	1,809,498	646,763
2025	2,651,112	4,125,108	1,833,127	653,356

BC=Bandung City; BR=Bandung Regency; WBR=West Bandung Regency; CC= Cimahi City

Table 5. Landfill Arising 2021-2025

Year	Incoming Landfill per Year (Ton)	Accumulated Landfill	
		Ton	m^3
2021	1,033,784	1,033,784	2,067,567
2022	1,047,620	2,081,404	4,162,808
2023	1,061,457	3,142,861	6,285,721
2024	1,075,294	4,218,155	8,436,310
2025	1,089,130	5,307,285	10,614,570

Based on the projection results, the landfill volume that enters the Sarimukti landfills until 2025 is 10,614,570 m3. The modelling results show that the remaining volume to reach the maximum capacity condition is 4,634,733.64 m3. In 2023, the landfill volume projection from Sarimukti landfills is 6,285,721 m3 and it will have reached its maximum capacity. The projection value in the Table 4 could be higher if the population and consumer consumption of packaged food and drinks were increased. Therefore, a solution model is needed to overcome this problem, such as the expansion of the area to accommodate landfill until 2025 and the expansion of the area must accommodate a landfill volume of 5,979,837 m3. Another solution is to look for a new landfill location, considering that Sarimukti landfills has been operating since 2006.

This research is different from other research that uses drones to calculate cut and fill volume. They usually implement this method on a mine area. The drones are usually used to map new mining areas or post-mining operations (mine restoration and rehabilitation) (Johansen, Erskine, dan McCabe 2019; Padró et al. 2019). This research shows that the use of drones is not only about mapping the extreme conditions (such as opening a mine area or post-mining area) and calculating cut and fill during visualising, but they can also be used as a prediction of the operational time of landfill areas and the estimated value of cut and fill volume in the next few years. This indeed depends on the statistical methods used in this research. According to (Ren et al. 2019), the challenges and prospects of UAV for the future will depend on the UAV platform and the type of sensor used, which can affect the accuracy and the efficiency of time, lower data acquisition costs, also higher precision of basic data (big data).

V. CONCLUSION

Drones can be used for monitoring landfills and calculating the existing and projection of landfill for the next few years. The calculation of the existing landfill volume from 2017 to 2021 was carried out using a 3D landfill model from drone visualisation. The contours of 2017 are set as the base plane (lower terrain) and the contours of 2021 as the results of data processing are set as the upper terrain. The value of landfill volume obtained from the 3D model is 5,495,254.35 m3. A comparison of the landfill volume obtained from the management data of trucks that entered the landfills from 2017 to 2021 is 5,707,052 m3. The difference in volume is relatively small, which is 211,797.64 m3, so the accuracy of the data is 96.29%.

Based on the 3D model of Landfill Capacity, the remaining volume to reach the maximum capacity is 4,634,733.64 m3. The projection of landfill arising until 2025 can be obtained by calculating the population projection, the coefficient of landfill arising, and the amount of landfill entering per year. The results show that in 2023, the landfill volume of Sarimukti landfills

which is 6,285,721 m3, will have reached its maximum capacity. On the other hand, the landfill volume that enters the Sarimukti landfills until 2025 is 10,614,570 m3. It is necessary to expand the area that can accommodate landfill until 2025 or equivalent to accommodate a landfill volume of 5,979,837 m3. Considering that Sarimukti landfills has been operating since 2006, it is recommended to look for a new landfill location.

VI. REFERENCES

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