



Volumetric Change Calculation for a Landfill Stockpile Using UAV Photogrammetry

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DOI: <https://doi.org/10.30880/ijie.2019.11.09.006>

Received 05 February 2019; Accepted 22 September 2019; Available online 30 December 2019

Abstract: A growth in population and urbanization is the major factor of accretion in municipal solid waste (MSW) generation in Malaysia. The higher percentage of MSW particularly in Peninsular Malaysia, a quantity of 16,200 tons per day in 2001 increase to 19,100 tons per day in 2005 which make an average of 0.8 kg/capita/day. The amount continues expanding yearly and approximately 8 million tons per day especially in urban areas. Hence, the landfill management has to design a landfill using basic design parameters method which use past record to complement with the correlation factor during the situation. However, this method will exert more time before producing the result. This research aims to consider the calculation of volumetric change calculation for a landfill stockpile using Unmanned Aerial Vehicle (UAV) photogrammetry and predict the targeted life span as an alternative method. The case study is located at Rimba Mas, Mukim Titi Tinggi, Perlis. The process involved throughout this study are planning and preparation before the flight, data collection using UAV, image processing and analyzing data from the image. This study focusses more on the method to calculate the volume using UAV photogrammetry and generate the data into Pix4dmapper. This observation took 2 months periodically to oversee the changes in volume at the landfill site. The result of analysis showed that, there were differences and increasing in the volume of waste for each months. The volume information obtained from UAV photogrammetry and the Pix4dmapper software can help in future for better plan in managing the landfill and MSW.

Keywords: Landfill, UAV Photogrammetry, volumetric change

1. Introduction

In Malaysia, about more than 10.40 million tons of municipal solid waste (MSW) being thrown away into landfills without proper integrated waste management and an average of 30,000 tons of waste were produced each day but only 5 percent of it is recycled [1]. This conveys that the importance of landfill in Malaysia. This statistic disclosed by the National Ministry of Urban Wellbeing, Housing and Local Governments recently and develop a huge issue to the nation. Therefore, the government keep on finding method to overcome this situation.

The majority used landfilling for waste disposal method in global because it is the easiest or uncomplicated and cost-effective technology that accessible nowadays [2]. In early years of 1970s, the disposal site cannot accommodate small communities because the disposal site is small and barely an open-dumping on the grounds. After decades with the

community continue to grow, a national program was started to manage the municipal and industrial waste consistently and preserve to be better each decade.

Apart from that, it is important to know the basic design parameters for the landfills which is the target lifespan that should be designed based on operational duration of the landfill site and should be set at approximately 10 to 15 years of operation after first formulating the plan [3]. This parameter is usually used globally when a targeted life span should be calculated because the design will support for the long term plan in implementing the adequate solid wastes treatment project.

Furthermore, a practical method of disposal is important in planning the final disposal site because it is obligatory to ascertain and establish the types and volume of waste for landfilling to produce a potent master plan for solid waste management based on the actual required of the area. There are several ways to calculate the volume of waste which is by using on site or offsite weighbridge, conversion factors or average tonnage system [4].

Conventionally, to produce the physical size and total area required, a volume which include landfilling and compacting volume of waste and covering materials is needed. The volume had to obtain for forecasting the life expectancy of the landfill. These may take a lot of time and causing in lagging while gaining the data because it will only produce when the landfill is full so that another cell can be predict for future usage. If that happens, it will increase the total cost to construct the landfill.

Conventionally, landfill used basic design parameters to produce targeted lifespan for a landfill which is determined by design landfill capacity. The value of annual designed volume will be needed in order to produce the data which will consume many years because the data use is from the past record that will not be the same as the population keep expanding every year. Thus, the correlation factor that will be used in the new design parameters will also be different.

The conventional method is found to have disadvantage which is the main problem when it consumed a lot of time that may takes several months to produce the data because the calculation required past record to find the correlation factor that is suitable for the situation at that time to produce the total volume of MSW. This is because, in the globalization era, with the expanding in the population, it required to have the data immediately to determine its size and area that is required to build a landfill that will cater all the citizen need.

As mention on the above, with the increment in per capita generation rate with the rise of living standard, it should be determined based on historical records and past trends which if there is insufficient information, the increment factor should be used as an approximate figure on condition that the review of the Master Plan be made based on the past trend. This may effect on the data that will be produced because of the unavailable information that is needed during the calculation of the basic design parameters for the landfill.

For future approach of landfill management, an alternative way of calculating the volume change for a landfill is to be determined by Unmanned Aerial Vehicle (UAV) as showed in Fig. 1. UAV is a device that can get geospatial data like high resolution orthophoto, Digital Surface Model (DSM), Digital Terrain Model (DTM) and 3D spatial models [5]. Despite, it also can conduct for stockpile volumetric calculation to see exactly how much space the landfill can accommodate which is beneficial for this research.



Fig. 1 - DJI Phantom 4 Pro that use in this research

Unmanned Aerial Vehicle (UAV) is a generic aircraft design to operate with no human pilot on board. The vehicle is controlled either autonomously by attached microprocessors or telemetrically by an operator on the ground that can be used to accomplish observation or detection missions through automatic or remote control [6]. UAV photogrammetry is a new photogrammetric measurement tool that opens various new applications in the close range domain, which combine the aerial and terrestrial photogrammetry, nevertheless introduce to a low-cost alternative to the classical manned aerial photogrammetry [7].

These UAV usefulness in civil engineering is mainly due to the low cost, fast speed, high maneuverability, and high safety of UAV systems for collecting images because it is already reliable replacement over satellites and manned vehicles that have overcome the disadvantage of low flexibility and high cost of aerial imagery. It also provides new opportunities for civil engineers despite the difficulties to obtain using conventional civil engineering tools. For civil engineering application, a survey area can be large and relying on remote control of vehicles by operators because it may not suffice. Therefore, it is necessary for automatic and semi-automatic navigation technologies to be employed.

Apart from that, the UAV images are valuable resources to extract the methods available when calculating the volume from the images obtained based on DEM. The UAV family drone hardware called "Phantom 4" will be used for data acquisition which is multi-frequency receiver for positional survey, Pix4dmapper software is used for data processing cum analysis [8]. Nowadays, it is critical to optimize the regular basis of a stockpile volumes which can determine the accuracy of how much raw materials was extracted than allow it to be effectively plan for subsequent activity of any stock yard.

Therefore, the UAV images will produce detail while correlating volume calculation algorithm to it. The accuracy volume calculation resulted in supporting minerals extraction optimization, financial estimation and stock estimation. Therefore, UAV images that is based on volume calculation will reduce the time and manual stock calculation efforts. When considering the use of UAV surveying method for stockpile volumetric, the first question asked is always about expected accuracy even though it is not trivial to answer though it is a common question that is simple.

The main objective for this project is to propose alternative method for determining the ultimate designed volume of landfill by using UAV photogrammetry. Apart from that is to analyze the data using Pix4dmapper as the new possibilities for assessment of ultimate designed volume of the landfill that has been developed.

2. Literature Review

With the statistics the total amount of MSW produced on this site is 330 tonnes / day consisting of 25 individual wastes with 39% composition of food waste, 12% plastic waste and 16% paper [9]. Whereas, the rural population produces 0.8 kg/cap/day seems to be the main problem to the consumption oriented urban middle-class that generates about 1.9 kg/cap/day of MSW [10]. Between 70 to 80 percent of municipal solid waste is placed in landfill at Malaysia approximately [11]. Landfilling always be the most common technique for many years due to urbanization because it is inexpensive for solid waste disposal which come from the primary sources that classified as residential area, institutional and commercial waste [12]

In manual calculation, to determine the designed landfill capacity (DLC), the sum of planned waste to be landfilled (ADLV) and soil covered (CMV) per year, must be calculated by the number of years that landfill is to be operated. To get the ADLV, the dividing of annual designed landfill weight (ADLW) by the specific weight (SWW) (or weight per unit volume) of the solid waste that is landfilled and compacted also must be calculated. Lastly, the cover material volume (CMV) shall be determined by dividing annual designed cover material weight (ADCMW) by the specific weight (SWCM) (or weight per unit volume) of cover material which is landfilled and compacted. Usually, after determining DLC, the site can secure the capacity of fills DLC that selected and the required area for landfill site dependable on the situation of a securable site. However, when DLC is first determined by the reason the site was already decide, target lifespan will change according to DLC [13].

2.1 Volume Changes Using UAV Photogrammetry

In this research, the UAV photogrammetry will be used to determine the volumetric change for a landfill stockpile. Before this, the calculation of the landfill volume is needed in determining the calculation for the basic design parameters. The formula of designed landfill capacity will produce the target or target year for a landfill towards finding a suitable site and carrying out the financial analysis and determining the construction schedule of the landfill beforehand the cell in the landfill to fill up and full. This conventional method can be a bit troublesome to obtain all the data needed because everything had to be taking into account to make sure correlation factor that used in the calculation is suitable with current situation.

Therefore, to avoid all of the disturbing factors which can delay the time in obtaining the data, UAV photogrammetry will produce estimated total volumes through the data that obtained from flying the drone at the landfill site. It is easy to operate UAV which offer a payload of up to 5 kg and can carry complex and heavy surveying systems, such as single-lens re-flex (SLR) cameras compared to the conventional method which require the weighing scale that cannot be transfer to somewhere else [14].

With that aerial images, it can generate the 3D models or DSM as the use of stereoscopic aerial photographic pairs to generate DSM's that has been extensively investigated for a review development of image-matching since 1960 [15]. So the result would be more precise with the 3D surface models and a higher accuracy for volume calculations, safer and faster than before.

Volume changes in landfill stockpile showed in Fig. 2 is by using UAV photogrammetry in Rimba Mas Landfill, the cell is divided into 3 main cell as in Fig. 3 which is cell 1 is bulky waste, cell 2 is garden waste, and cell 3 is domestic waste cell.



Fig. 2 - Piles of bulky waste at Rimba Mas Landfill.



Fig. 3 - The cell at Rimba Mas Landfill.

3. Methodology

This research is split into six principle phase; which is Phase 1 is preliminary study, Phase 2 is planning and preparation, Phase 3 is data collection, Phase 4 is data processing, Phase 5 is data analysis and finally, Phase 6 is conclusion and recommendation.

3.1 Flight Planning and Preparation

At Rimba Mas Landfill, three cells of domestic waste, bulky waste and garden waste are being used and the route for image acquisition would be around the cell that have the MSW volume. A DJI Phantom 4 Pro has been set at 100 m flight altitude from the ground to avoid any disturbance and the orientation use double grid 3D models to navigate the route of drone. The images were taken automatically.

Before flying the drone, a ground control point (GCP) should be taken as needed to calibrate the images in the software. The GCP is taken by using Real-time Kinematic (RTK) global positioning system GPS. RTK-GPS can be assumed as the dynamic type of GPS positioning technique that provides most accurate result (with roughly millimeters error) in real time [17]. Table 1 showed the GCP's coordinate of Latitude, Longitude and Elevation which refer to Ellipsoid height. The GCP is mark using a red spray in Fig. 4 with the size of 1m x 1m so that it would be seen in the images. Fig. 5 showed 19 GCP's that had been set up by the landfill management but some of them are not available anymore because of the road embankment has been built for easy access.

Table 1: The GCP's of latitude, longitude and elevation coordinate at the landfill.

| | Latitude | Longitude | Elevatio |
|--------|------------|------------|----------|
| GCP 1 | 6.59865310 | 100.271709 | 33.225 |
| GCP 2 | 6.59938686 | 100.269838 | 34.096 |
| GCP 3 | 6.59866229 | 100.271424 | 33.236 |
| GCP 4 | 6.5983024 | 100.270405 | 29.556 |
| GCP 5 | 6.59883854 | 100.271243 | 29.795 |
| GCP 6 | 6.59892313 | 100.270723 | 27.91 |
| GCP 7 | 6.59930798 | 100.271566 | 33.166 |
| GCP 8 | 6.60063539 | 100.270712 | 33.081 |
| GCP 11 | 6.59760080 | 100.270509 | 32.416 |
| GCP | 6.59761313 | 100.271248 | 28.735 |
| GCP | 6.59611927 | 100.271340 | 30.439 |
| GCP | 6.59671830 | 100.271924 | 31.142 |
| GCP | 6.59581600 | 100.272359 | 28.374 |
| GCP | 6.59535413 | 100.272069 | 28.412 |
| GCP | 6.59732379 | 100.272179 | 31.946 |
| GCP | 6.59819043 | 100.273017 | 26.317 |
| GCP | 6.59786245 | 100.271659 | 32.338 |



Fig. 4 - Temporary ground control point that should be in (1m x 1m) size at the Rimba Mas landfill.



Fig. 5 - Location of ground control point that scattered around at the landfill.

For better result in generating the volume, it is best to use in 3D mode showed in Fig. 6 which in the months of July 2018 compared to 2D model (Fig. 7) in August 2018 because it has a higher overlay level, which has more image information for the software to reconstruct an object thus more detailed 3D model. Nevertheless, a higher data implies will consume more time spent for flying and acquiring images and longer processing time. Because of that, there is some option that can be used to manage the angle between images that helps to balance the time and quality so that it allows faster and more schematic reconstructions to become more detailed.

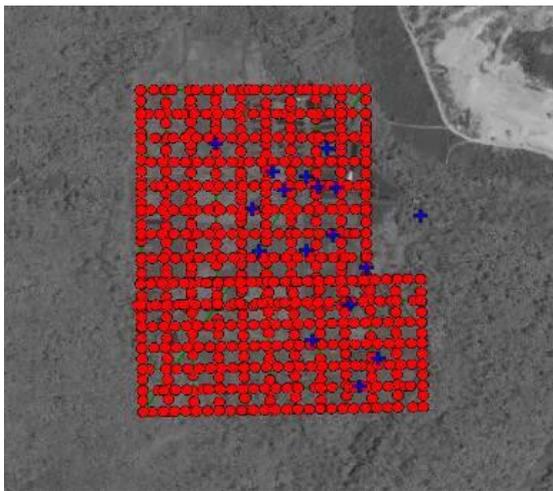


Fig. 6 - The orientation of the flight route for image acquisition that is in 3D double grid models

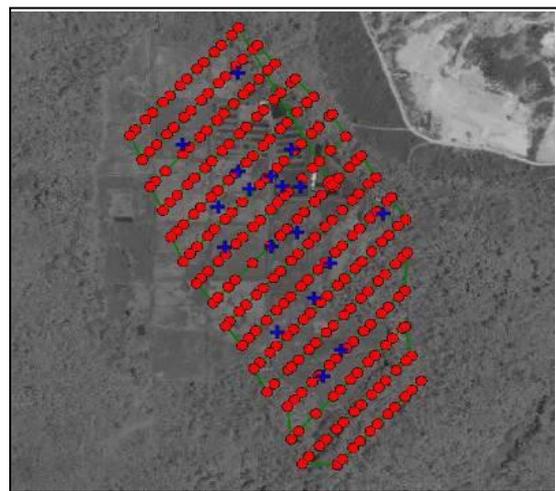


Fig. 7 - The orientation of the flight route for image acquisition that is in 2D grid for maps

4. Data Collection

For collecting data, it was planned to fly about 2 times in 2 months to get the volume difference. The UAV controller and UAV were connected to the iPad with IOS application control which is Pix4dcapture before the flight. Pix4dcapture is opened and connected to the UAV and the Global Positioning Systemic (GPS) will calibrate the camera to be vertically 90° during the flight when capturing the area. For the flight plan and parameters, it has been set up to 100 m high of altitude. In this research, the first flight takes around 24 minutes to cover half of the area and another 15 minutes for second flight. It has to be divided into two flight because the battery cannot accommodate to fly once if using it in 3D mode whereas if using it in 2D mode it will take about 25 minutes to cover the whole area without having to change the battery

During the flight, if emergency occur such as insufficient amount of battery left, the UAV can be call back by press the home button and then it will land at the same place where it started. After changing the battery, the flight plan can be continued as usual because it will continue with the last flight plan it stop before this.

After the flight completed, the pilot ratified the result by checking the images directly on the application to avoid inconvenient remapping by reviewing the mission while still on the site.

5. Data Processing

To process the images, UAV images were inserted into the Pix4dmapper to begin the data processing. In processing options showed in Fig. 8, three stages involved where the initial processing, point cloud and mesh processing and lastly DSM, orthomosaic and index processing will occur during this stage. For reducing the processing time, all resources available should be maximize. Then, click start to begin the local processing.

For the first flight in 15 July 2018, about 773 images have to be process in the Pix4dmapper because the 3D double grid mode were used whereas in 15 August 2018, only 261 images were being process that is in 2D grid mode.

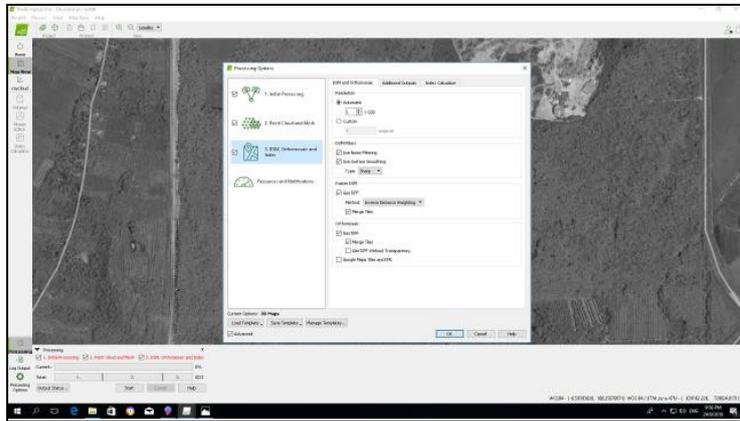


Fig. 8 - Three stages of data processing

When the full process is completed, only then the volume data can be generated. To calculate the volume showed in Fig. 9 until Fig. 11 click on the insert volume icon and get the new volume to be inserted in the mapper. First, add a new volume and click on the volume around the cell by left click and then right click to finish off the volume and compute. Fig. 12 showed part of the processing in Pix4dmapper.



Fig. 9 - Volume stockpile at bulky waste cell



Fig. 10 - Volume stockpile at garden waste cell



Fig. 11 - Volume stockpile at domestic waste cell

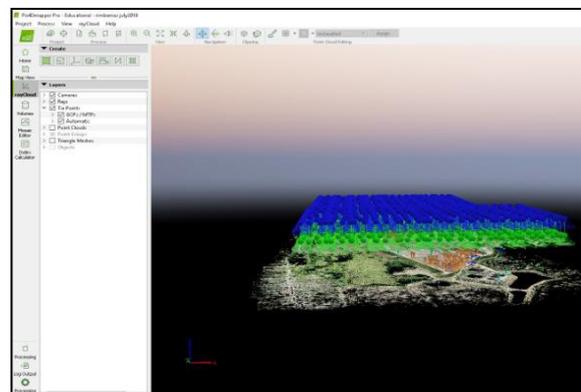


Fig. 12 - Process of building mesh

6. Results and Discussion

Pix4dmapper calculate the volume by using the DSM. To get a new volume, the point cloud and the DSM should be generated. The altitude of vertex must be taking into account to create the base in the software. After that, the software projects a grid with ground sampling distance (GSD) spacing on the base. From that, it generates the result by using the formula created by the software.

Then, it will show the fill volume, cut volume and total volume as in Fig. 13 and Fig. 14. For this research a cut volume was used. The cut volume is calculated by using positive value while fill volume is calculated by using negative value. So that, the volume difference is equals to cut after minus with cut before thus when the volume difference has positive value it can be conclude that the material was added. For total volume it is computed based on the adding of cut and fill volumes. The advantage of using Pix4dmapper is that the volume measurements are exclusively based on the DSM that allows more accurate volume measurement.

The usage of GCP's in larger areas are required for accurate measurement. To determine the volume, at least two images is needed to calculate the error by marking the vertices if a base [16]. Thus, the ability of Pix4dmapper in customizing the base surface can perform accurate stockpile volume that provide 6 different bases surface defining options. In getting more precise stockpile of volume the high resolution photogrammetric is interpolated from certain measured points horizontally. It is found to be beneficial when a high ground sampling distance (GSD) is taller than the flatter stockpile which they lower the uncertainty in Elevation values that is proportional to the resolution vertically.

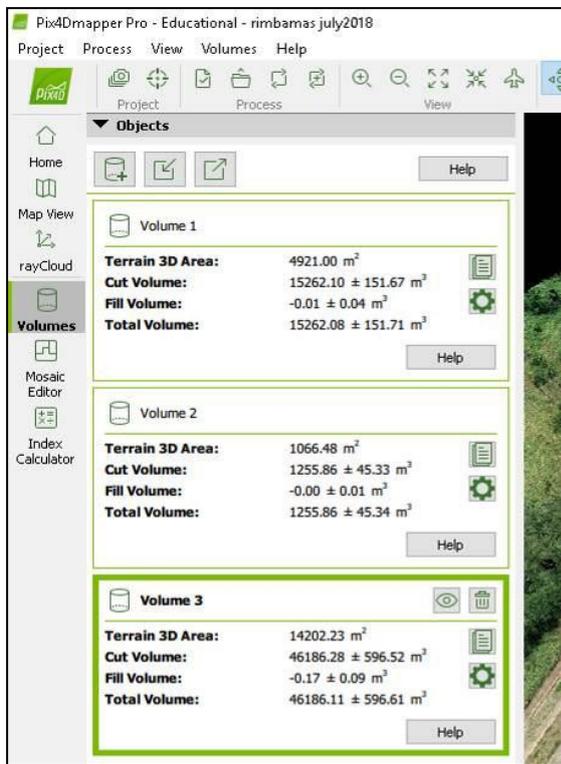


Fig. 13 -Volume calculation in 15 July 2018

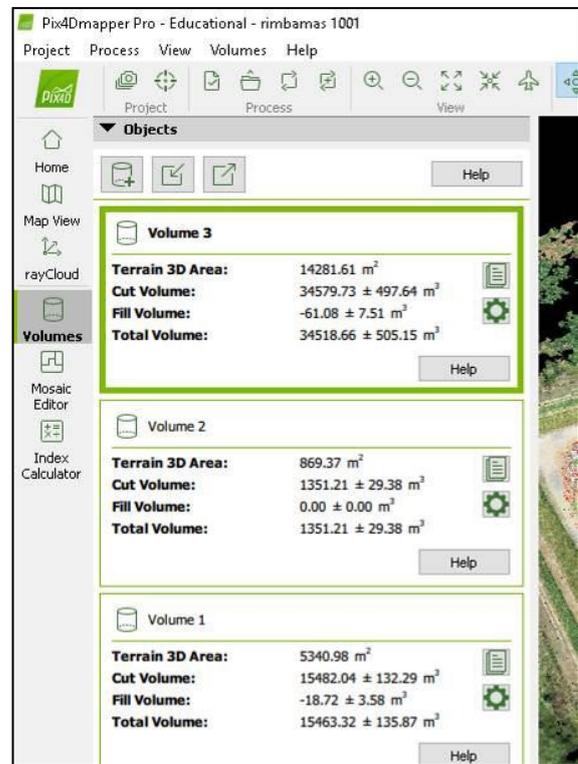


Fig. 14 - Volume calculation in 15 August 2018

Table 2 showed the result of the volume of MSW in Rimba Mas Landfill. Note that, cell 1 is bulky waste cell, cell 2 is garden waste and cell 3 is domestic waste. Based on the result, it shows that there are differences and increasing in the volume of waste for each cell every month which is the differences between the month of July and August for cell 1 is about 219.94 m³ whereas for cell 2 is 95.35 m³. But for domestic waste cell, the volume decreases from July to August about -11.606.55 m³ is because during that time the landfill management has decided to cover up the waste by filling with soil and compact it will roller. Landfill as thick as 0.5 m will be freed every day as a preventive measure for disposal problem of rubbish everywhere, bad smell and rain water diffusion. Despite, in the final stage a 1.5 m thick will be plastered hence the operations routes can still be used although during rainy day.

For further result in this research, a Global Mapper has been used to create the cross section and profiles for each stockpile to compare the result. The result shows that there is changes in the volume stockpile when generating it into the graph in Fig. 15 until Fig. 17 for each cell used at the landfill.

Table 2: Data comparison between July and August 2018

| | Cell 1 | Cell 2 | Cell 3 |
|------------|----------|---------|---------|
| 15 July 18 | 15,262.1 | 1255.86 | 46186.2 |
| 15 Aug 18 | 15,482.0 | 1351.21 | 34579.7 |
| Total | 219.94 | 95.35 | - |

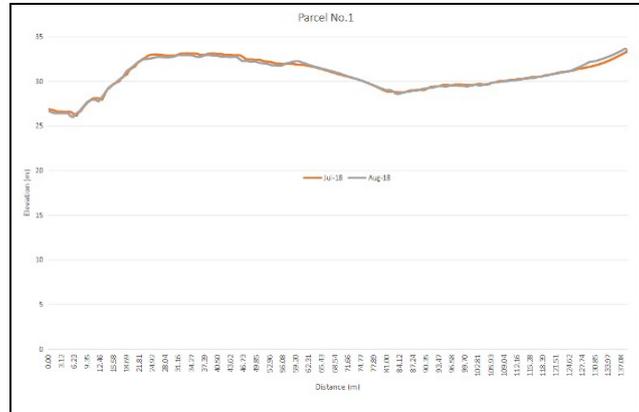


Fig. 15 - Profile changes in the month of July and August 2018 for bulky waste cell.

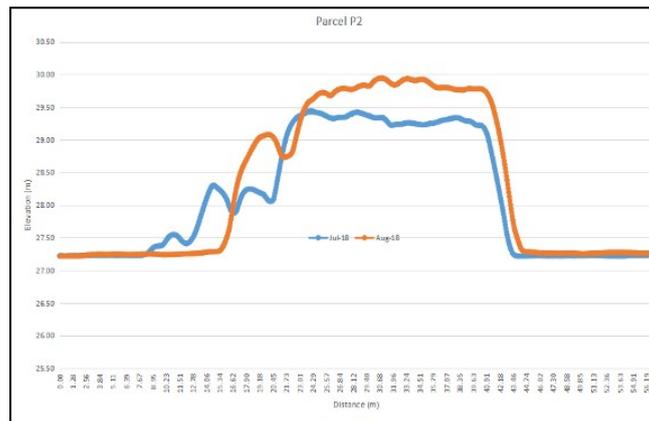


Fig. 16 - Profile changes in the month of July and August 2018 for garden waste cell.

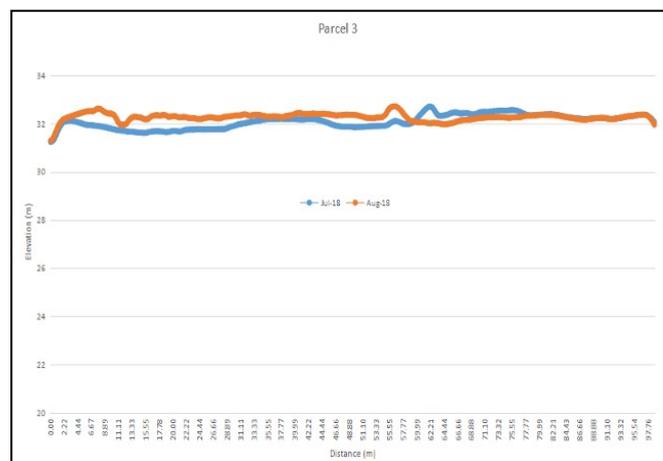


Fig. 17 - Profile changes in the month of July and August 2018 for domestic waste cell.

As for each stockpile, a 3D view is provided to allow users in viewing gridded elevation data and for whichever overlying raster or vector data in a true perspective 3D mode as in Fig. 18 until Fig. 20 for each waste stockpile.



Fig. 18 - 3D view for bulky waste cell

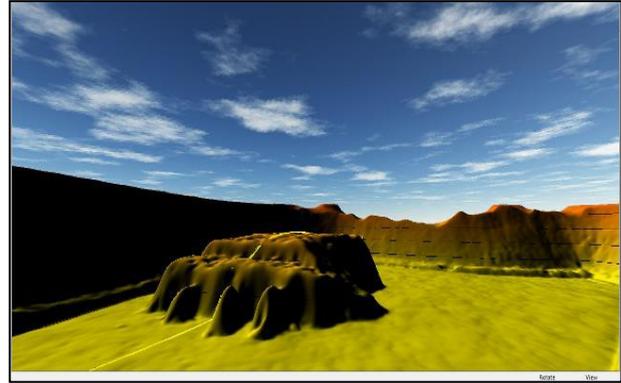


Fig. 19 - 3D view for garden waste cell

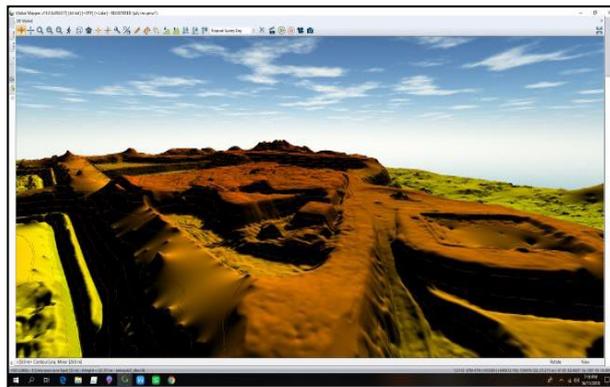


Fig. 20 - 3D view for domestic waste cell

To conclude, the UAV photogrammetry can be dependable to find the volume stockpile at landfill. The result can be very helpful to the landfill management in achieving a sustainable landfill. By using UAV flight, it can be the alternative way in producing volume at the landfill in a short time and economical to users. Other than that, the UAV has the ability to produce a high resolution orthophoto volume with low cost involved.

7. Summary

This research demonstrated the use of a low cost UAV in image acquisition process for volumetric change for a stockpile volume at landfill located at Rimba Mas Landfill. Volume of the landfill waste has been calculated using the Pix4dmapper which is user friendly that makes it easier to calculate the volume. For better volume estimation, the result showed that it required more captured images. Other than that, the greater number of GCP used can extremely improve the estimation results. To conclude, it has been showed that low cost UAV had a potential to calculate the volume of MSW with lower error. Besides, the time consume and cost can be reduced by using this alternative method. Apart from that, the suggestion for further research is that the volume of MSW has to be observed more than 2 months to get a significant difference between each month.

Acknowledgement

The authors would like to express their appreciation to all parties who have contributed to this research, especially to Research Grant TIER 1 Vote H264, Research Management Centre (RMC), UTHM.

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