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The Application of Unmanned Aerial Vehicle (UAV) For Slope Mapping at Gambang Damai Residents, Pahang: A Case Study

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Abstract: This paper highlights the work of slope mapping utilizing the unmanned aerial vehicle (UAV) with its perimeter, area, and volume of particular regions chosen at Gambang Damai Residents in Kuantan Pahang. The location selected was choose because of its proximity to the study area. Slope mapping has traditionally been time-consuming and challenging, especially in hilly areas. This research also aimed to identify potential slope hazards based on slope angle. The accuracy and nature of typical mapping outputs, such as the Digital Elevation Model (DEM) and Digital Orthophoto, depend on high-quality photos that modern UAVs can only capture. These photographs taken by the UAV will be transferred to Agisoft software to generate a complete map of the study area. With the help of Global Mapper, it's easy to measure elements such as the perimeter, area, and volume of selected study areas, which is the main point of this research. The results of the two slopes (slope A and slope B) show that slope B produces a massive volume of 1469.7 m3, whilst slope A generates just 1382.9 m3. Slope A has an enclosed area of 1634.3 m2, which is more significant than slope B's enclosed area of 766.86 m2. Additionally, slope A's perimeter is 162.28 m, more extensive than slope B's 159.45 m. Another result of this research is that researchers and engineers may evaluate potential slope hazards using a contemporary mapping approach by determining their particular slope angles. According to the findings, slope A has an angle of 47.35º, while slope B has an angle of 54.75º. Both slopes considered to be very steep. In conclusion, using current technology, such as UAVs, is quite beneficial when mapping in geotechnical engineering. Researchers and engineers can gather slope measurements more quickly than with previous traditional approaches by adopting multi-rotor UAV slope mapping.

Keywords: Unmanned aerial vehicle (UAV), slope mapping, slope hazard, slope angle

1. Introduction

The technology employed in gathering data regarding terrain profiles has seen tremendous advancement in recent years [1]- [3]. With the development of advanced technology at this time, the equipment used to gather all the data about the earth's surface becomes more accurate, compact, and saves time [4]- [6]. Apart from that, one of the UAVs is classified as airborne. It is a small aircraft, sometimes called a micro plane, that can be piloted from a remote location

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using a platform attached to a camera [7]. Time savings in data capture make this photography technology preferable to traditional or human surveying methods [8]. A digital orthophoto captured by a UAV is an image produced by a vertical parallelogram that projects a surface and possesses both an image's visual quality and a map's geometric precision [9]. The digital elevation model (DEM), a spatial information tool that contains land elevation profiles, is necessary for geomorphological applications. The only essential qualities that may be extracted using DEM are the slope, aspect, profile curvature, and trend [7]. Therefore, compared to alternative methodologies such as in-situ surveying, topographic mapping, and remote sensing, the gathering of data with UAVs assists in both speeding up and simplifying the process.

Engineers and geotechnical researchers may be able to work together more quickly and safely through the utilization of UAVs since they enhance their ability to detect possible slope failures, critical slopes, and slope hazards, as stated by Zolkepli et al [10], Ishak, & Zolkepli[11], Zolkepli et al. [12], and Bar et al. [13]. UAV flight technology has enabled the acquisition of high-resolution, real-time aerial pictures for photogrammetry to detect the location of potential slope hazards [14], [15].

1.1 Traditional Mapping

As a result of advancements in ground surveying, which employs theodolites and Total Stations, as well as aerial surveying, it is now much easier to determine the elevation of the land surface. This method is indeed challenging, and it requires surveyors who are both meticulous and highly experienced [16]. Lehmann et al. [17] state that numerous scholars have investigated the topic of low-cost surveying projects and slope mapping using satellite images. In contrast to satellite photography, which is limited to a certain amount of time for capturing images in a specific location, unmanned aerial vehicles (UAVs) are capable of moving freely within the same area for an entire day [18]- [21].

1.2 Slope Measurement

According to Ishak et al. [22], Zolkepli et al. [23], and Zolkepli et al. [24], slope measurements such as cut volume (m3), cut area (m2), fill volume (m3), fill area (m2) and perimeter (m) can be calculated by using Global Mapper software. Thus, the target of this work is to use a UAV, typically referred to as a drone, to acquire a digital orthophoto and a digital elevation model (DEM) of two selected slopes, slope A and slope B, located at Gambang Damai Residents in Kuantan. In addition, the perimeter, area, and volume of both slopes will be determined during this procedure. Moreover, this study will be expanded by identifying potential slope hazards based on the location of potentially hazardous areas based on various slope angles.

2. Methodology

2.1 Study Area

The study location is in Gambang Damai Residents in Kuantan Pahang. This place was approximately 11 kilometres from Universiti Malaysia Pahang. The surrounding area encompasses a wide variety of topographical features. Due to the absence of obstacles in the airspace, the UAV can navigate this area readily. This location was chosen because it lacked hazardous prey species such as hawks and eagles. Fig. 1 illustrates the survey area.

Fig. 1 - Study area (Google Maps)

2.2 Data Acquire & Data Processing

The DJI Phantom 4 Pro is the most commonly recognised drone design of the Phantom quadcopter family and is a high-technology drone [25]. It weighs about 1.38 kilogrammes (kg) and can be purchased from DJI. Remarkably, this UAV can travel at a speed of 72 km/h. In sport mode, the maximum speed for climbing is 6 metres per second (m/s), and the maximum speed for descending is 4 metres per second. The sensor of the DJI Phantom 4 Pro camera measures 1 inch and has 20 megapixels. It can capture video in 4K at 60 frames per second (fps) and still images in Burst Mode at 14 fps [26]. The DJI Phantom 4 Pro may be seen in Fig. 2, and it was utilised throughout this study. The features and capabilities of the DJI Phantom 4 Pro are detailed in Table 1.

Fig. 2 - DJI Phantom 4 Pro

Table 1 - UAV specifications

No.	Parameters	Details
1	Takeoff Weight	1388 g
2	Diagonal Size	350 mm
3	Max Speed (near sea level, no wind)	72.4 km/h (S-mode) 49.9 km/h (P-mode)
4	Maximum Takeoff Altitude	6000 m
5	Internal Storage	8 GB

All of the photographs that the UAV of the study area took are loaded into Agisoft Metashape Pro after the data from the UAV has been imported there. The engineering software automatically generates a digital orthophoto and a digital elevation model (DEM). Furthermore, Global Mapper version 18.1 was utilized to figure out the perimeter, area, and volume of the various chosen slopes. In order to visualize the topographical profile of each slope, it is also possible to use commercial software that assists in creating a cross-section of the area defined for research. Furthermore, commercial software can assess the potential slope hazard to determine which areas are at high risk of probable slope failure. Since it does not provide a large amount of error for the results that were obtained, the ground control points (GCP) are not appropriate to utilize in this case study.

A standard approach generally acknowledged by many researchers and practitioners has adopted acquisition. The steps involved in acquiring an image are shown in Fig. 3, as follows. The average altitude employed for this slope mapping was determined to be 300 m above mean sea level, which was done earlier, before flight planning. The resolution used for these mapping is 4k (2160p). The datum used in this study is WGS84 (Projection UTM, Zone 48 (102º E - 108º E- Northern Hemisphere).

2.3 Field Work and The Flight Mission

The use of unmanned aerial vehicles (UAVs) to retrieve photographs of terrain is essential and required. Flight planning is required before aerial photography. Flight planning requires consideration of flying height, the area coverage, focus length, scale, and coordinates. Actual size image collection relies significantly on time and weather data that can be inferred from aerial shots of the research location. This information could impact the quantity of visible light in the photographs. The optimal time to take aerial photographs of the research area to achieve the highest possible image quality was between 3 and 6 p.m. In order to assist photogrammetric analysis, the images were shot with a high degree of detail, considering all of the pertinent aspects. Fig. 4 shows the flight route for slopes A and B.

2.4 Global Mapper

Global Mapper version 18.1, a piece of software that can create multi-dimensional digital elevation models, was utilized for the research project. This version created digital slope dimensions for the locations selected to have slopes. The development of Global Mapper 18.1 has been a substantial endeavor, and it features excellent design, setup, and layer management. Additionally, it comes with several functional changes centered on the processing of 3D data. The three-dimensional (3D) display is a dynamically rendered representation of all the data loaded into an object. It presents the facts in a format that is consistent and comprehensive. The dynamic presentation process enables the creation of 3D maps and data sets with minimal effort. It facilitates the work of developers by enabling them to generate high-resolution maps and data sets with minimal effort and in a short amount of time. The most recent display engine in 3D Views now supports viewing on multiple surfaces. This feature enables planes to be positioned on various surfaces while maintaining a lower-than-typical viewpoint.

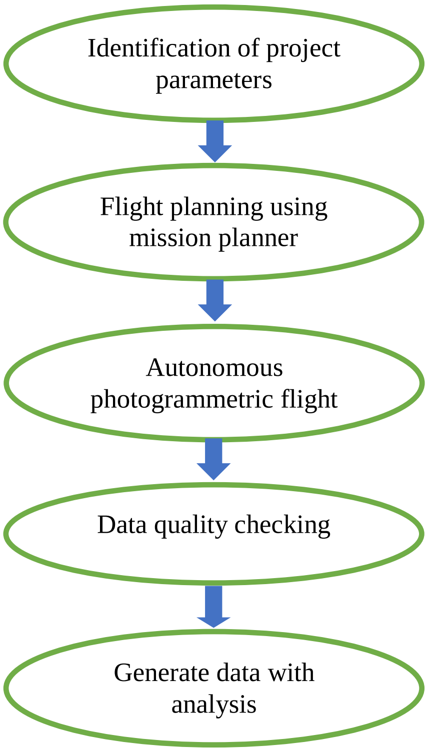


Fig. 3 - Workflow for data acquisition [12], [13]

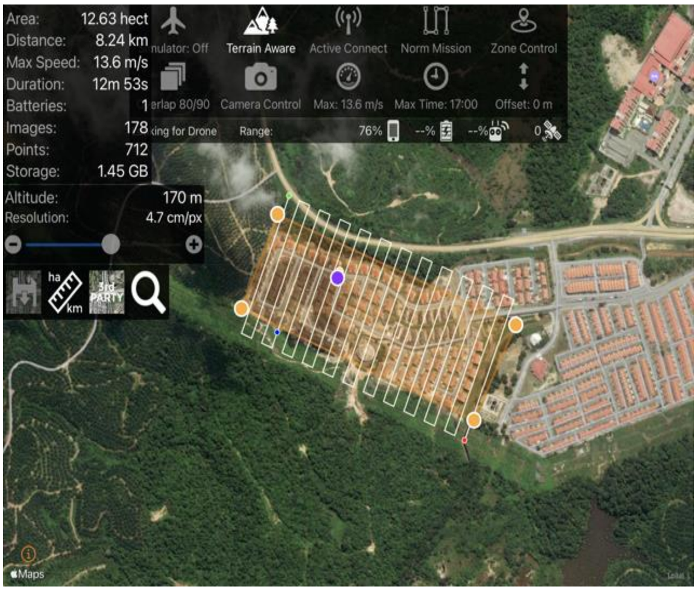


Fig. 4 - Flight path for slope A and slope B

3. Results and Discussion

3.1 Digital Orthophoto

Slopes A and B were chosen for additional analysis because both had already failed owing to excessive rainfall. Both the digital orthophoto and the digital elevation model (DEM) displayed these slopes in their respective formats. Fig. 5 is an image of the area studied that was taken with a UAV and provided as a digital orthophoto. Fig. 5 is a digital orthophoto captured by an unmanned aerial vehicle (UAV).

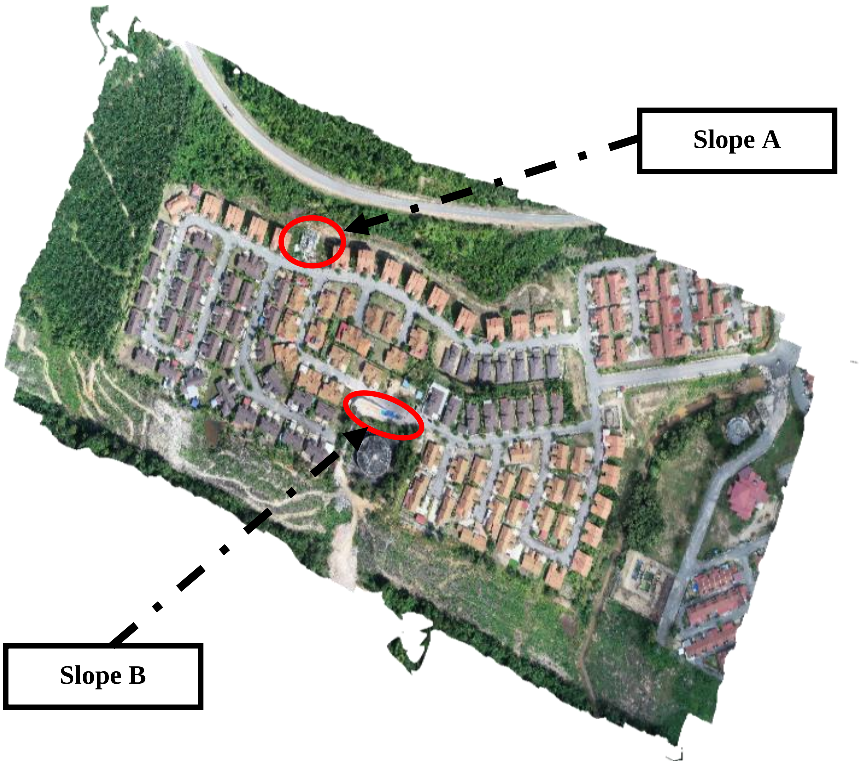
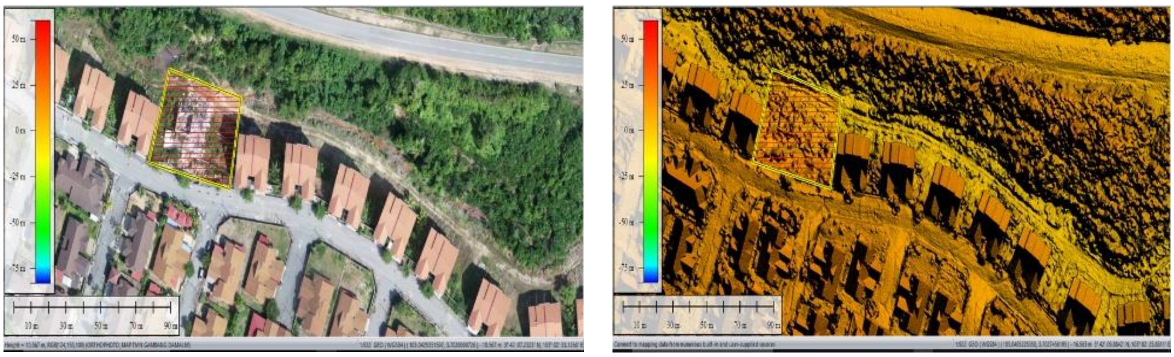


Fig. 5 - Digital orthophoto by Unmanned Aerial Vehicle (UAV)

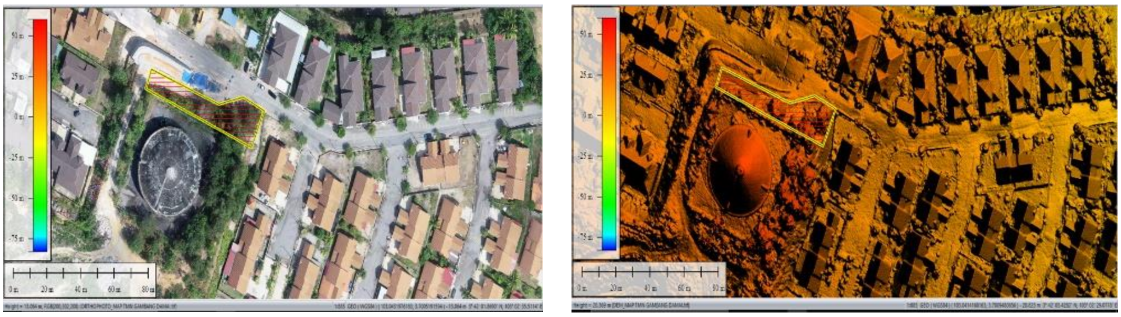
3.2 Digital Orthophoto and Digital Elevation Model (DEM)

The map was presented in both digital orthophoto and digital elevation model (DEM) formats for both slope A and slope B of the terrain. Both of the maps were necessary for the subsequent analysis. The digital orthophoto and DEM for slope A is respectively viewed in Fig. 6, while the digital orthophoto and DEM for slope B can be viewed in Fig. 7.



(a) (b)

Fig. 6 - (a) Digital orthophoto of slope A; (b) Digital Elevation Model (DEM) of slope A



(a) (b)

Fig. 7 - (a) Digital orthophoto of slope B; (b) Digital Elevation Model (DEM) of slope B

UAVs are not only useful for image acquisition, but also for determining the volume, area, and perimeter of various locations. The measurement profile of slope A and slope B are presented in Table 2.

Table 2 - UAV specifications

Measurement	Slope A	Slope B
Total Volume	1382.94 m^3	1469.17 m^3
Cut Volume	264.99 m^3	669.54 m^3
Cut Area	385.24 m^2	303.28 m^2
Cut Area 3D	543.41 m^2	584.61 m^2
Fill Volume	1117.95 m^3	799.63 m^3
Fill Area	1243.60 m^2	460.99 m^2
Fill Area 3D	1441.10 m^2	714.60 m^2
Enclosed Area	1634.30 m^2	766.86 m^2
Perimeter	162.28 m	159.45 m

According to Table 1, the total volume of slope A is 1382.94 m3, while the entire volume of slope B is 1469.17 m3. Next, the cut volume for slope A is 264.99 m3, and for slope B it is 669.54 m3. Slope A has a cut area of 385.24 m2, while slope B has a cut area of 303.28 m2. The fill volume of slope A is 1117.95 m3, and the fill volume of slope B is 799.63 m3. The slope A fill area is 1243.60 m2, while the slope B fill area is 460.99 m2. Furthermore, the perimeter of slope A is 162.28 m, and slope B's is 159.45 m. Based on the overall volume for both slopes, it may be concluded that slope B was more prominent than slope A.

3.3 Potential Risks of Slope Hazard

Before constructing a structure, it was necessary to determine the slope angle. When assessing the slope hazard, the slope angle must be addressed because it may contribute to the slope hazard. As indicated by Galloway & Zachery [27], the slope classes are shown in Table 3, respectively. Fig. 8 presents the potential slope hazard for slope A.

The coordinates (103.0414991709, 3.7020320122) and (103.0415429983, 3.7021317573) denote the area in which the vertices that were chosen may be located. The selected vertex has a point with a height of 2.57m, and the point with a height of 2.04m is the lowest point of the selected vertex. A horizontal distance of 0.473m separates these two vertices. The angle of slope that is formed by these two vertices is 47.35^{o}. According to Table 2, the specified slope falls within the classification of Class G, which denotes a very steep gradient. As a result, it can be categorized as a potential slope hazard. The potential hazards that could be posed by slope B are depicted in Fig. 9.

Fig. 8 illustrates the path profile of the cross-section of Slope B. The coordinates (103.0421400700, 3.7005801313) and (103.0421737097, 3.7006516157) denote the range in which the chosen vertices may be located. The selected vertex has a range of elevations, with the highest point measuring 23.655m and the lowest measuring 22.23m. A horizontal distance of 1.023m separates these two vertices. The angle of slope that is formed by these two vertices is 54.75^{o}. According to Table 3, the chosen slope belongs to Class G, which denotes a very steep gradient. As a result, it can be categorized as a potential slope hazard.

Table 3 - Summary table for classes of slope

Researcher	Classes of slope	Angle of slope	Condition of slope
[27]	A	0.2	Nearly level
	B	2-6	Gently sloping
	C	6-12	Moderately sloping
	D	12-18	Strongly sloping
	E	18-25	Moderately steep
	F	25-35	Steep
	G	35-100	Very steep
	Classes of slope	Angle of slope	Condition of slope

(a) (b)

Fig. 8 - Potential slope hazard for slope A

(a) (b)

Fig. 9 - Potential slope hazard for slope B

Table 3 - Summary table for classes of slope

Slope	Horizontal Distance (m)	Slope Angle (^{0})	Classification
A	0.473	47.35	Very steep
B	1.023	54.75	Very steep

4. Conclusion

Based on the findings of this research, the applications of UAVs are very beneficial. These applications include slope mapping due to their low cost, low time consumption, simple operation, and ability to quickly acquire a large volume of data. This advanced technology will be of assistance in research as well as business development, making the process simpler and more efficient. By combining data from UAVs and well-known software, the researchers in this study can obtain vital characteristics and information regarding the topography of the area under investigation. Other than that, the measurements of the study area, such as its perimeter, area, volume, and more, can be obtained precisely. Table 1 shows that slope B was more extensive than slope A based on the total volume for both slopes.

Finally, applying UAVs allows for additional expansion, as it can be applied to determine the potential hazards associated with slopes based on the angles. According to Galloway & Zachery [27], there are seven (7) different classes of slope angle, each of which has its own class and condition. The angle of slope A has been identified to be 47.35º, while the angle for slope B was identified to be 54.75º. Very steep slopes can identify Slope A and Slope B since the slope angles range from 35º to 100º.

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