© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

Unmanned Aerial Vehicle (UAV)-Based for Slope Mapping and the Determination of Potential Slope Hazard

M. F. Zolkepli[1], M. F. Ishak[1,2*], Z. Abu Talib[3]

[1]Facultyof Civil Engineering Technology,
Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Kuantan, Pahang, MALAYSIA

[2]Earth Resources and Sustainability (ERAS),
Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan, Pahang, MALAYSIA

[3]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2022.14.01.021
Received 20 May 2020; Accepted 12 September 2021; Available online 07 March 2022

Abstract: This paper discusses the applications of unmanned aerial vehicle (UAV) for slope mapping and the determination of potential slope hazard of three selected areas. With the development of modern technology, the utilization of UAV to gather data for slope mapping can be considered as finest method as it is quick, reliable, precise, cost-effective and also easily to operate. High imagery quality is essential for the effectiveness and nature of normal mapping output such as Digital Surface Model (DSM) and also Ortho Images. The utilization of UAV to capture aerial photo helps to gather information from a normal area to an area which almost impossible to reach. With the data obtained by the UAV, it will later process in established software and the analysis of slope profile of certain selected study areas will be done. Mapping using UAV was within the area of Pahang Matriculation College. Three slope area namely as Area 1, Area 2 and Area 3 are marked. Further analyses are conducted in these three areas to obtain the information of potential slope hazard based on slope angles. For Area 1, the slope is marked at the coordinate of (286136.265, 412066.821) to (286265.423, 411783.038). The slope angle between the two vertexes was 46.18° and considered as very steep slope. For Area 2, the slope is marked at the coordinate of (286054.203, 412021.343) to (285963.651, 411913.543). The slope angle between the two vertexes was 77.66° and considered as very steep slope. The slope at Area 3 is marked at the coordinate of (285847.833, 411775.762) to (285887.450, 411251.046). The slope angle between the two vertexes was 47.43° and considered as very steep slope. In conclusion, the use of UAV in geotechnical engineering proven to be very useful for slope mapping and determination of slope hazard based on slope angle.

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

1. Introduction

Nowadays, the instruments use for data acquisition in geological topography have been rapidly improved. With the development of modern technology, the equipment used to gather all information related to earth surfaces becomes cheaper, smaller, accurate and can gather large amount of data within a short period of time [1]-[3]. These devices are light, mobile, easily to operate, completely automated and providing access to almost unavailable study areas. Advances in UAV technology have enabled the acquisition of high-resolution and real-time aerial images for photogrammetry [4]-[6]. With the help of UAV, the effectiveness of land monitoring together with existing infrastructures can be conducted within a short time period compare to conventional techniques, especially for urgent cases like natural disasters [7], [8].

*Corresponding author: fakhrurrazi@ump.edu.my

Recently, the use of unmanned aerial vehicle in research study and also commercial term are ending up progressively normal [1], [2]. According to [9], geophysical surveys in mountains and natural terrains are normally challenging due to the site conditions, which may affect the quality of data acquisition. Unmanned aerial vehicle (UAV) or known as drone allow for the effectiveness of monitoring which cover large area of land and infrastructures within a very short time interval compare to conventional techniques [10].

UAV has developed during the last decades. They operate remotely in the form of small platform, attached completely with camera and available as small or micro aircrafts [10]. UAV photogrammetry provides information used for image stitching. Autopilot system guarantees planned flight path, camera triggered auto-control to take a picture at every waypoint [1].

Engineers and researchers who involved in geotechnical and soil works always faced problem regarding slope stability. These problems usually happened in term of slope mapping and slope monitoring works [11]-[13]. A stable slope is the ability of slope to sustain its sustainability [14]-[20].

The aim of this paper is to determine the potential slope hazard of three selected study areas located at Pahang Matriculation College located at Kuantan, Pahang by using unmanned aerial vehicle UAV or commercially known as drone. This work of finding potential slope hazard was based on their respective slope angles. For every slope area (Area 1, Area 2 and Area 3), the location of slope was marked to their respective coordinates and their angles were determined.

2. Research Methodology

The study area is at Kuantan, Pahang. The site area consists of different terrain profile. This site is completely free from any distraction and obstacle on the air for UAV to freely move around. Fig. 1 shows the map of study area. The perimeter of this study area is 3370 m and the enclosed area is 765836 m^2. The duration of time needed for overall mapping using UAV is about 30 minutes.

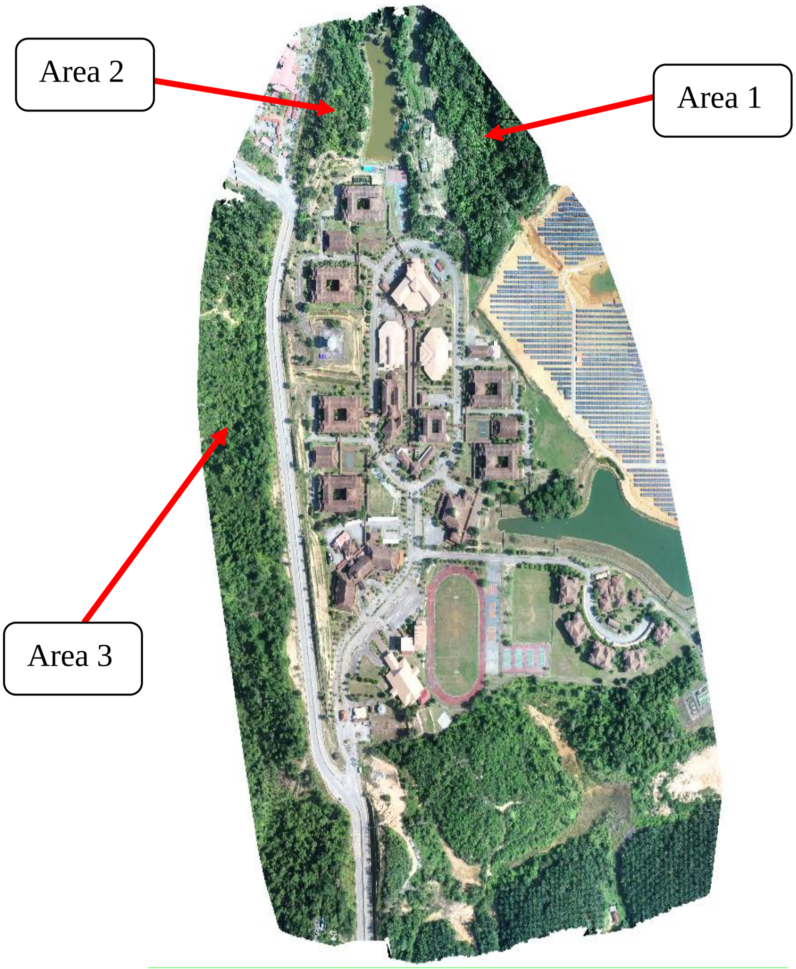


Fig. 1 - Map of Pahang Matriculation College generated using unmanned aerial vehicle

2.1 DJI Inspire 2 and Technical Specifications

The DJI Inspire 2 weight around 3.44 kg makes it a powerful and high technology drone. This UAV has a speed of 94 km/h which make it pretty impressive. The max ascent speed is 6 m/s in sport mode and the max descent speed is 4 m/s. The length of this UAV is 42.7 cm, with height of 31.7 cm and width of 42.5 cm. DJI Aspire 2 has a maximum transmission distance of 7 km and is capable to deliver both 1080p and 720p video. Fig. 2 shows the image of DJI Inspire 2. Meanwhile, Table 1 shows the specification and features of DJI Inspire 2 and Table 2 shows the camera specifications of the UAV.

Fig. 2 - DJI Inspire 2

Table 1 - Specification of DJI Inspire 2

Parameters	Details
Flight time	25-27 minutes
Speed	94 km/h
Sensory range	30 m
Battery	98 Wh dual battery
Raw video recoding	Yes
Ports	USB and HDMI
Obstacle avoidance system	Yes
Control range	7 km
Video resolution	5.2K and 4K
Live View	1080P
Remote controller frequency	2.4 GHz and 5.8 GHz
Design material	Magnesium aluminium composite shell with carbon fibre arm

Table 2 - Camera specifications

Parameters	Details
Camera Model	Zenmuse X4S
Resolution	5472 x 3648
Focal Length	F/2.8-11, 8.8 mm
Pixel Size	20 MP
Operation Modes	Capture, record, playback
Shutter Speed	Mechanical Shutter: 8-1/2000s Electronic Shutter: 1/2000-1/8000s
ISO Range	100-6400 (video) 100-12800 (stills)
Video Captions	Supported
Anti-Flicker	Auto, 50Hz, 60Hz

2.2 Image Acquisition

The normal workflow accepted for image acquisition has been used by many researchers and practitioners. Following are the steps for image acquisition as in Fig. 3. The result obtained from UAV monitoring will then be transferred into global mapper version 18.1 for the analysis.

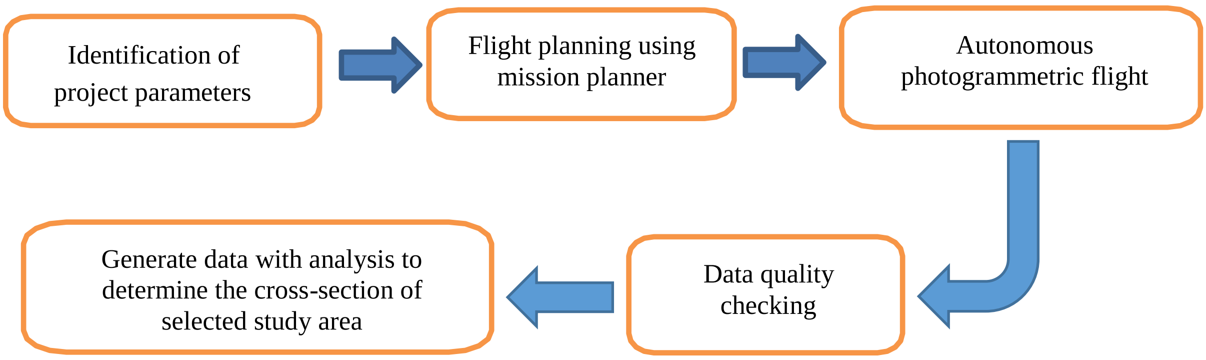


Fig. 3 - Workflow for data acquisition

In the early stage of UAV mapping, the first stage is to identify the project parameters. This is very important since the aim and objective is the most important things that need to be determined first before flight. Researchers must understand and know why they do mapping and what for. The second stage is by flight planning using mission planner. To fly a UAV model DJI Inspire 2, software known as DJI Map Pilot need to be used. Researcher need to plot every details of location covered for mapping. The UAV will capture the images of the area that had been plotted. The third stage for this mapping is the autonomous photogrammetric flight. In this stage, the UAV will capture all the images needed by the researcher through the gimbal attached at the bottom of UAV. This gimbal model is Zenmuse X4S.

The duration of flight mapping require only 30 minutes to complete the image acquisition at study area. The fourth stage is data quality checking. Here, researcher will check all the images captured by UAV whether it satisfies the need of researcher. The camera model Zenmuse X4S is able to capture high resolution images up to 4k or 2160p. Finally, the images captured by UAV will be converted into 3D map for further analyses by using commercial software known as PiX4D. This map is presented in two types of data which are Digital Orthophoto and Digital Surface Model (DSM). Digital Orthophoto present the actual map of the study area while DEM present the elevation profile of the map.

After obtaining the map, the next step is by doing the analyses using Global Mapper. Global Mapper is a powerful software which are able to analyze the slopes in detailed. The Global Mapper needs to read both Digital Orthophoto and DSM in order to do further analyses. As presented in this paper, the final analyses will include the determination of the cross-section of selected study areas and determine potential slope hazard based on slope angles.

3. Results and Discussion

The result of this study is presented in digital orthophoto and with their respective path profiles for the determination of potential slope hazard based on slope angle. The ground control points (GCP) are not used in this study as it does not give much error for the results obtained. The independent orthoimages are used to generate digital orthophoto in photogrammetric process.

3.1 Slope Hazard

Slope angle is the most important thing that need attention before any construction work. In order to determine the slope hazard, the angle of the slope need to be consider since it is one of the factor that cause the slope hazard to be occur. As indicated by [3], [21], the slope classes is shown in the Table 3.

Table 3 – Slope Classes [21]

Classes of slope	Angle of slope (°)	Condition of slope
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

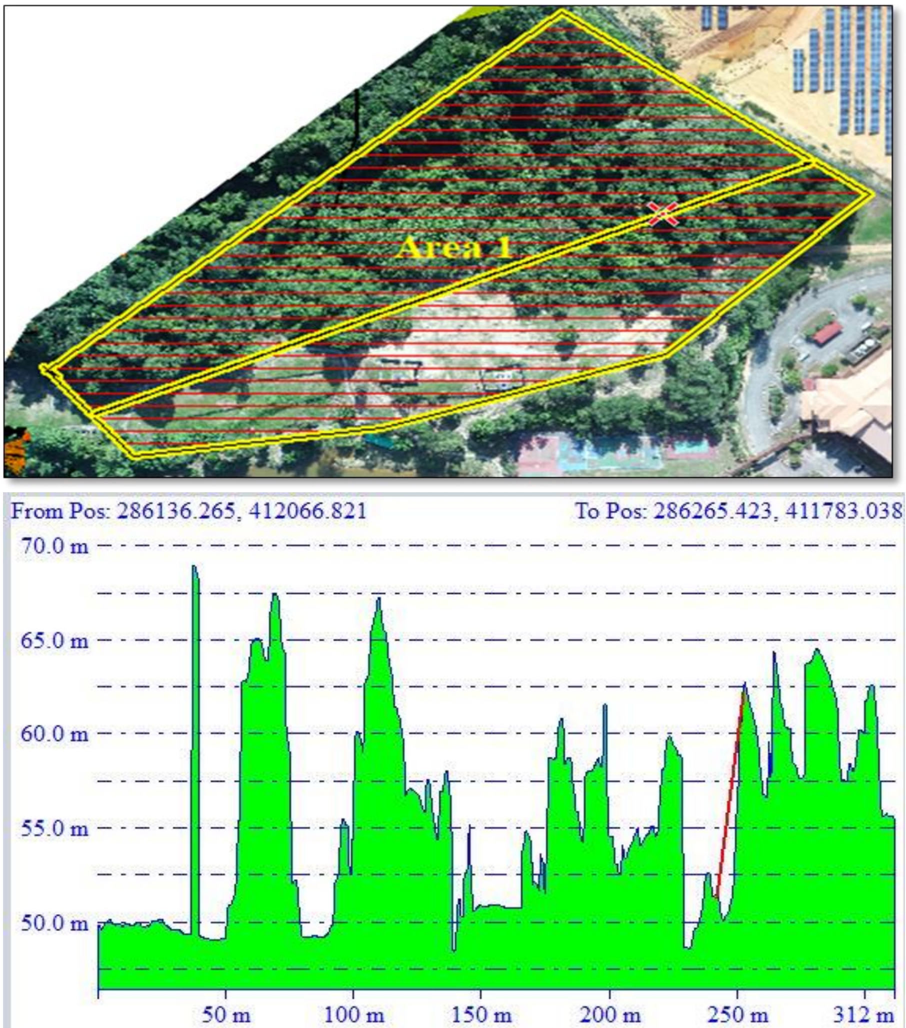
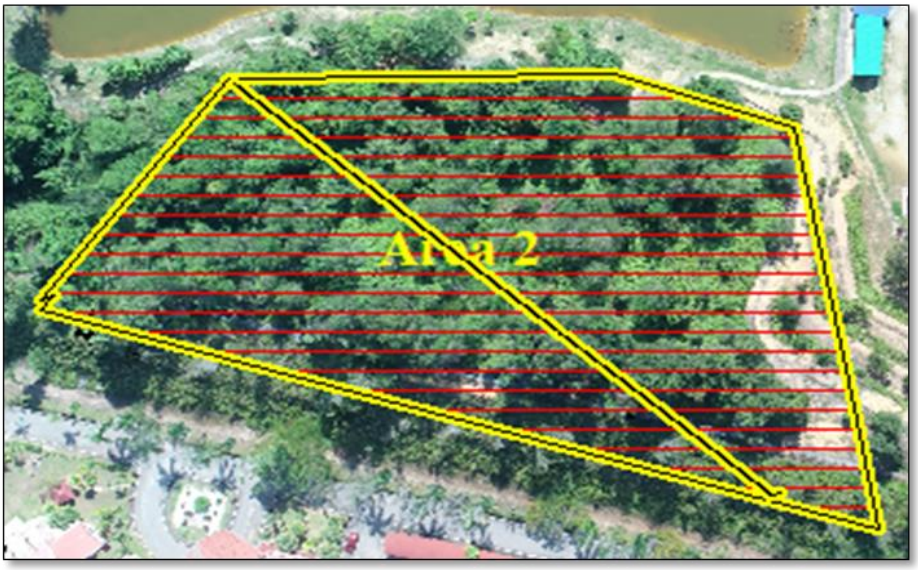


Fig. 4 - Path profile of area 1

Fig. 4 show path profile of Area 1 consist of several vertexs with different height. The selected vertex was located at the coordinate of (286136.265, 412066.821) to (286265.423, 411783.038). The first height of selected vertex was about 51.288 meter while the second vertex was about 62.201 meter. The distance between these two points were 10.48 meter in the x-axis. The selected slope angle between the two vertexes was 46.18° which based on the classes of slope, the condition of slope was considered as very steep slope and classified as the slope hazard since it angle is in range from 35° to 100°.

From the Fig. 5, the chosen points of Area 2 were located at the coordinate of (286054.203, 412021.343) to (285963.651, 411913.543). The first height of selected point was about 54.391 meter while the second point was about 68.134 meter. The distance between these two vertexes were about 3.00 meter in the x-axis. The selected slope angle between the two vertexes was 77.66° which based on the classes of slope, the condition of slope was stated as very steep slope since it angle is in range from 35° to 100° and classified as the slope hazard. Figure 6 show the path profile of Area 3.



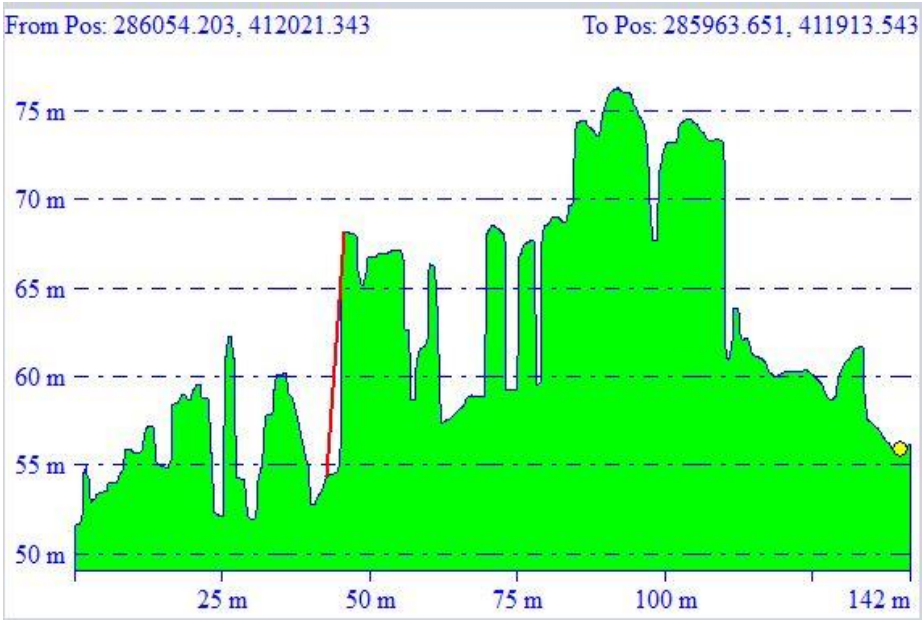


Fig. 5 - Path profile of area 2

From the Fig. 6, the selected points of Area 3 were located at the coordinate of (285847.833, 411775.762) to (285887.450, 411251.046). The first height of selected point was about 42.812 meter while the second point was about 52.764 meter. The distance between these two vertexes were about 9.14 meter in the x-axis. The selected slope angle between the two vertexes was 47.43° where based on the classes of slope, the condition of slope was stated as very steep slope since it angle is in range from 35° to 100° and classified as the slope hazard. All of these analyses is accordance to previous researchers such as [3], [6]), who also do research for slope mapping using UAV. They also indicate the potential slope hazard based on slope angle that been analyzed by using Global Mapper. Overall, it can be concluded that modern technology of UAV can help engineers and researchers in the field of geotechnical engineering to monitor and maintain slope stability.

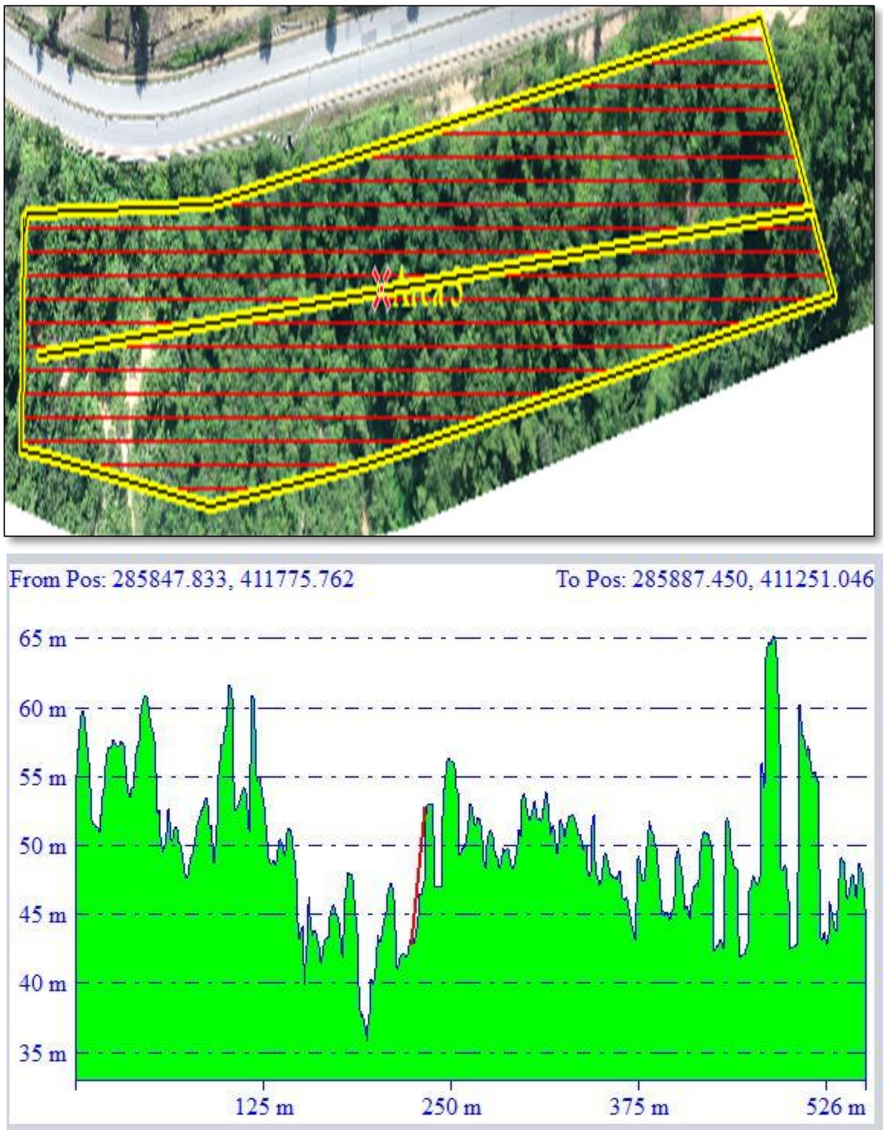


Fig. 6 - Path profile of area 3

4. Conclusion

From this study, the use of UAV has proven to be very effective for slope mapping. This modern technology requires short time interval for slope mapping and can quickly gather huge amount of data. This modern technology will help in research and also commercial works which make work easier and faster. In this study, with the combination of data from UAV and also established software, researchers are provided with important parameters and information about geological and topography of their study area. Other than that, the elevation of the selected study area can be determined which helps in researches and also commercial works to determine the profile of high area such as slopes and many more. From this determination, researchers can locate the potential slope hazard from the slope angle obtained from software analysis. This can be considered as early safety precaution that needed attention by engineers before proceed with any construction work.

Acknowledgement

The authors would like to express their gratitude to Universiti Malaysia Pahang for Grant (RDU1903144- Application of Digital Surface Model to Investigate the Potential Slope Hazard) that served as full financial support to conduct this research. Thank you to all BTC staffs (Faculty of Civil Engineering Technology, Universiti Malaysia Pahang) for their kindness and full support to conduct this research from the start until finished.

References

[1] Kumar, N. S., Ismail, M. A. M., Sukor, N. S. A., & Cheang, W. (2018). Geohazard reconnaissance mapping for potential rock boulder fall using low altitude UAV photogrammetry. IOP Conference Series: Materials Science and Engineering, 352, 012033.

[2] Kumar, N. S., Ismail, M. A. M., Sukor, N. S. A., & Cheang, W. (2018). Method for the visualization of landform by mapping using low altitude UAV application. IOP Conference Series: Materials Science and Engineering, 352, 012032.

[3] Zolkepli, M. F., Ishak, M. F., Yunus, M. Y. M., Zaini, M. S. I., Wahap, M. S., Yasin, A. M., Sidik, M. H. & Hezmi, M. A. (2021). Application of unmanned aerial vehicle (UAV) for slope mapping at Pahang Matriculation College, Malaysia. Physics and Chemistry of the Earth, 123, 103003.

[4] Park, S., Lee, H., & Chon, J. (2019). Sustainable monitoring coverage of unmanned aerial vehicle photogrammetry according to wing type and image resolution. Environmental Pollution, 247, 340-348.

[5] Turner, I. L., Harley, M. D., & Drummond, C. D. (2016). UAVs for coastal surveying. Coastal Engineering, 114, 19-24.

[6] Zolkepli, M. F., Rozar, N. M., Ishak, M. F., Sidik, M. H., Ibrahim, N. A. S., & Zaini, M. S. I. (2021). Slope mapping using unmanned aerial vehicle (UAV). Turkish Journal of Computer and Mathematics Education, 12(3), 1781-1789.

[7] Greenwood, W., Zekkos, D., Lynch, J., Bateman, J., Clark, M., & Chamlagain, D. (2016). UAV based 3-D characterization of rock masses and rock slides in Nepal. In 50th US Rock Mechanics/Geomechanics Symposium, American RockMechanics Association, Houstan.

[8] Tannant, D. D., Giordan, D., & Morgenroth, J. (2017). Characterization and analysis of a translational rockslide on a stepped planar slip surface. Engineering Geology, 220, 144-151.

[9] Ismail, M. A. M., Kumar, N. S., Abidin, M. H. Z., & Madun, A. (2018). Systemic approach to elevation data acquisition for geophysical survey alignments in hilly terrains using UAVs. Journal of Physics: Conference Series, 995, 012104.

[10] Tziavou, O., Pytharouli, S., & Souter, J. (2018). Unmanned aerial vehicle (UAV) based mapping in engineering geological surveys: Considerations for optimum results. Engineering Geology, 232, 12-21.

[11] Ishak, M. F., & Zolkepli, M. F. (2016). Exploration of methods for slope stability analysis influenced by unsaturated soil. Electronic Journal of Geotechnical Engineering, 21(17), 5627-5641.

[12] Ishak, M. F., & Zolkepli, M. F. (2017). Exploration of method for slope stabilization influence by unsaturated soil. Science International, 29(1), 105-108.

[13] Zolkepli, M. F., & Ishak, M. F. (2017). Exploration of methods for slope stabilization influence by unsaturated soil. Malaysian Journal of Civil Engineering, 29(2),121-131.

[14] Zaini, M. S. I., Ishak, M. F., & Zolkepli, M. F. (2020). Monitoring soil slope of tropical residual soil by using tree water uptake method. IOP Conference Series: Materials Science and Engineering, 736 072018.

[15] Yue, L. J., Ishak, M. F., Zaini, M. S. I., & Zolkepli, M. F. (2019). Rainfall induced residual soil slope instability: Building cracked and slope failure. IOP Conference Series: Materials Science and Engineering, 669 012004.

[16] Zolkepli, M. F., Ishak, M. F., & Zaini, M. F. (2019). Slope stability analysis using modified Fellenius's and Bishop's method. IOP Conference Series: Materials Science and Engineering, 527 012004.

[17] Goh, J. R., Ishak, M. F., Zaini, M. S. I., & Zolkepli, M. F. (2020). Stability analysis and improvement evaluation on residual soil slope: Building cracked and slope failure. IOP Conference Series: Materials Science and Engineering, 736 072017.

[18] Ishak, M. F., Zolkepli, M. F., Yunus, M. Y. M., Ali, N., Kassim, A., & Zaini, M. S. I. (2021). The effect of tree water uptake on suction distribution in tropical residual soil slope. Physics and Chemistry of the Earth, 121, 102984.

[19] Ishak, M. F., Zolkepli, M. F., Yunus, M. Y. M., Ali, N., Kassim, A., & Zaini, M. S. I. (2021). Verification of tree induced suction with numerical model. Physics and Chemistry of the Earth, 121, 102980.

[20] Zolkepli, M. F., Ishak, M. F., & Zaini, M. S. I. (2018). Analysis of slope stability on tropical residual soil. International Journal of Civil Engineering and Technology, 9(2), 402-416.

[21] Jaafar, S. A. N. (2020). Identification of Slope Hazard from Profile using Unmanned Aerial Vehicle (UAV). Final Year Project, Universiti Malaysia Pahang.