3-D Recording of Slope Failure in Indonesian Tropical Peatland by UAV-photogrammetry

Yamaguchi University	Non member	○I GD Yudha Partama
Yamaguchi University	Member	Ariyo Kanno
Yamaguchi University	Member	Koichi Yamamoto
Kyoto University	Non member	Noerdin Basir
Riau University	Non member	Sigit Sutikno

1. Introduction

Peat failure in Bengkalis Island is occurs after the significant land use change from peat swamp forest to palm oil plantation. The construction of many canals in the plantation caused the water balance is not well distributed in time and space, and made the water table lower and the peat material in the surface became easily to dry. Therefore, when the rainy season comes, the stability of the peat slope will reduce and cause the peat failure (Sutikno *et al.*, 2017).

Peat failure monitoring requires continued assessment of the extent, rate of displacement, surface topography, and detection of the fracture structures. This is very important to improve our understanding of the peat failure processes, identify the mechanisms that trigger the slope failure, and develop methods for peat failure susceptibility mapping. For this reason, the topographic data (i.e., Digital Surface Model) are indispensable information source in such engineering geological assessment of peat failure.

Airborne light detection and ranging (LiDAR) has been utilized in a wide number of environments to provide high resolution topographic data. Nevertheless, this technique is too costly to apply to a wide area, so frequent repeat survey are, therefore, not always feasible. In recent years, development of the SfM-MVS method, which is a semi-automatic image-processing based computer vison technology, has provided the opportunity for low-cost three-dimensional data acquisition.

This method greatly reduces the level of expertise and ability to extract high resolution and accurate spatial data, using cheap consumer-grade digital small format cameras mounted on Unmanned Aerial Vehicles (UAVs) (e.g., drones). The aim of this study is to apply the UAV-based SfM-MVS method for monitoring the slope failure in tropical peat land area.

2. Methods

2.1 Study area

The study area is located in north part of Bengkalis Island, Riau Province, Indonesia which lies 10 km off the coast of Sumatra along the west side of Malaca Strait as shown in Fig. 1. The study area is almost flat and has maximum surface elevation of approximately 10-15 m above sea level (Sutikno *et al.*, 2017). The study area is dominated with oil palm plantation. The characteristic of peat deposit in Bengkalis Island is five domes, which has maximum thickness approximately of 6 to 10 m (Subekty *et al.*, 1993). To demonstrate the SfM-MVS techniques described in this study we selected the active peat failure area as the main trial site (Fig. 1, yellow rectangle).

2.2 UAV survey

Aerial imageries were collected using a stock camera (4K/ultra-high-definition camera; angle of view: 94 degrees; resolution: 4000 x 3000 pixels) on a small, lightweight (1.38 kg), quad-copter UAV (a DJI Phantom 4) (Fig. 2A). We set the camera to point directly downward (nadir), because this is the most basic and widely used setup.

Keywords: MVS, SfM, peat failure

連絡先　〒755-8611　山口大学工学部社会建設工学科　神野有生

ＴＥＬ0836-85-9310

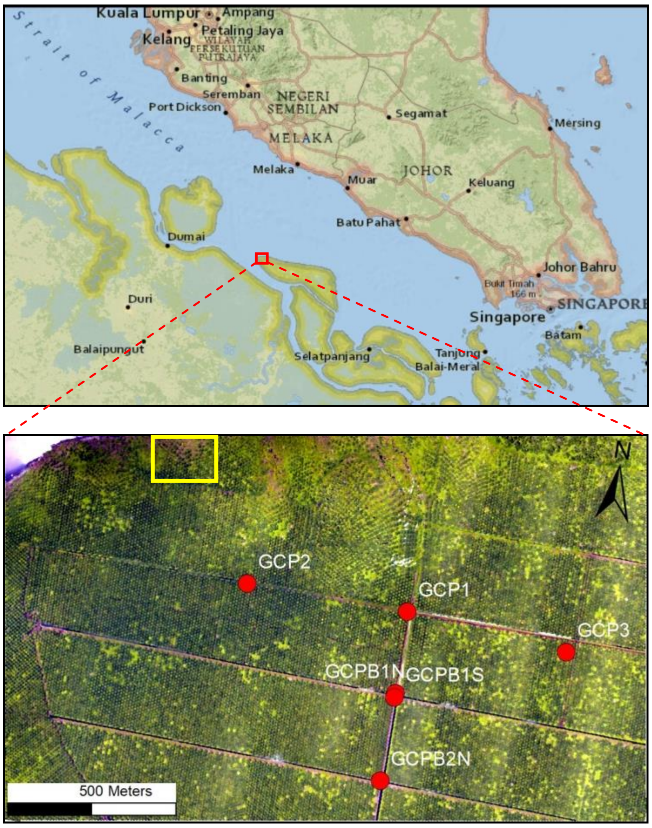

Figure 1. The study area and the GCPs distribution overlaid with orthophoto.

Further, the ISO and exposure times was set to 100 and 1/532 sec, respectively. The resulting image footprint size was approximately 800 m x 600 m. The total number of images collected in this study was 1078.

2.3 Global navigation satellite system (GNSS) survey

Six ground control points (GCPs) were installed across the study site for geo-referencing and bundle adjustment purposes in the SfM-MVS method (Fig. 1). These points were defined at the center of the square orange markers sheets with the size of 2 m x 2 m. The coordinates of the center marker were measured in the field directly after UAV image acquisition using a Trimble R8s GNSS system (Fig. 2B) which provide centimeter positional and height accuracies (2-3 cm).

2.4 SfM-MVS for 3-D model generation

The data acquisition-image processing workflow is summarised in Fig. 2 (A-G). We generated the 3-D model of the peat failure using commercial software, Agisoft PhotoScan Professional version 1.3.4. First, SfM was performed to estimate the camera's extrinsic and intrinsic parameters, as well as the XYZ coordinates of the sparse point clouds. The GCPs were used for geo-referencing of the 3-D model in a real-world coordinate system and to adjust some intrinsic parameters by using bundle adjustment method. Obvious outliers were deleted from the sparse point cloud to reduce reconstruction errors. MVS was performed to obtain the dense point clouds. Finally, the model were exported to a grid based orthophoto and DSM, and 3-D mesh polygon. Residuals for the GCPs were calculated as an initial indication of the geometric accuracy of the model.

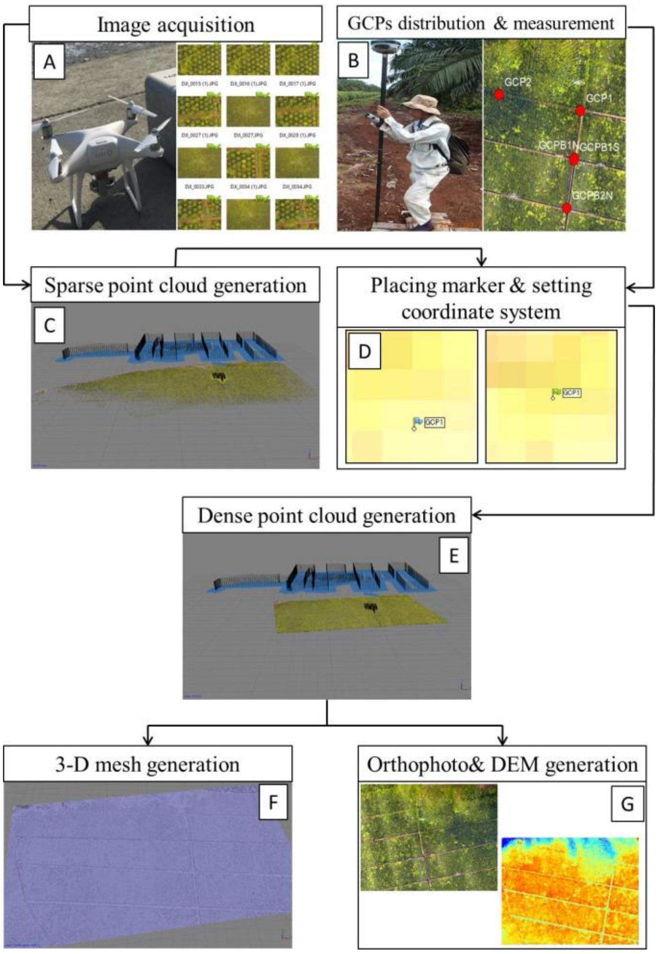

Figure 2. Data acquisition and SfM-MVS processing workflow.

3. Results and Discussion

Figure 3 shows the orthophoto, DSM, and 3-D mesh polygon generated from UAV-based SfM-MVS method at a peat failure area. The spatial resolutions of the orthophoto and DEM yielded from this method were 0.17

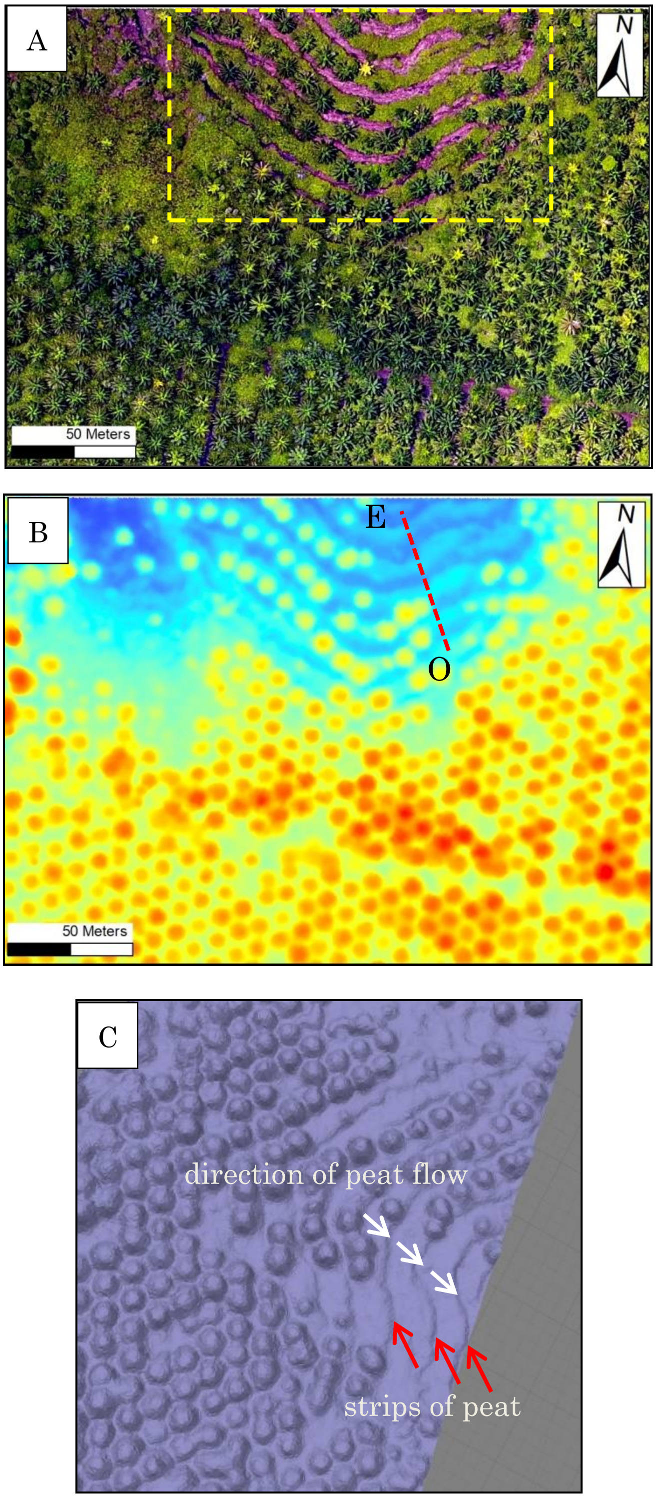

Figure 3. Peat failure models generated from UAV SfM-MVS: (A) georeferenced orthophoto; (B) DSM; and (C) 3-D mesh polygon.

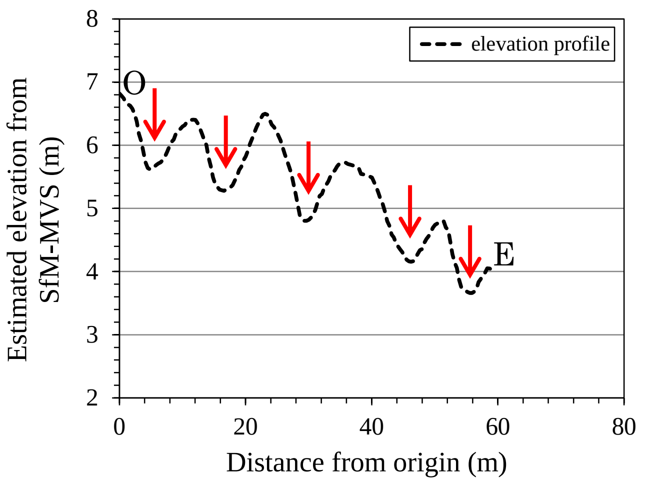

Figure 4. Elevation profile from O to E (Figure 3A). Red arrows show the displacement due to the peat failure.

and 0.34 m, respectively. The accuracy of the 3D models was assessed based on the residuals of the georeferencing and bundle adjustment. The overall RMSR (XYZ coordinates) of the 3-D surface model was 0.294 cm.

Based on visual interpretation of the orthophoto, the peat failure has occurred in the north part of Bengkalis Island. This characterized by presence of the terraced on the coastal peatland due to the peat sliding towards to the ocean (Fig. 3A, yellow rectangle). As evidence, we have analysed the elevation profile along cross section line through peat failure area (Fig. 3B, red-dash line). As a result, the elevation is gradually decreased from point O to E (Fig. 4). In addition, the subsidence which caused the terraced shape is also visible in this graph (Fig. 4, red arrow).

The key engineering of geomorphological features such as the failure shape, surface topography, and the direction of the peat flow are clearly recorded from the 3-D mesh polygon (Fig. 3C). The peat failure in this area was spread laterally causing damage of plantation land and coastal area. On the other hand, the transformation of the peat dome (raised bog) into strips of peat (Figure 3C, red arrow) indicate that the peat failure in Bengkalis Island is classified as a bog burst type (Dykes and Warburton, 2007).

Overall, this study presents a mapping workflow for peat failure based on UAV imagery and SfM-MVS algorithms at tropical peatland. This technique allowed the possibility of detailed mapping of engineering geological landforms at a range of spatial scales. As the above example demonstrates, the application of UAV-based SfM-MVS represents an effective, financially viable alternative to traditional topographic surveying and iDAR, particularly for practical application in remote, inaccessible regions.

4. Conclusion

In this study, we used a UAV platform equipped with a small format digital camera to collect a set of images over the peat failure area in Bengkalis Island. Structure from Motion (SfM) and multi-view stereovision (MVS) methods were used to convert thousands of overlapping images into a 3-D point cloud, 3-D mesh polygon, DSM, and orthomosaic with 0.2 m ground resolution. Our results indicate that a combination of UAV-based imagery and SfM-MVS methods succeeds in recording the 3-D model and the geomorphological features of the peat failure in detail. This allows for flexible, cost-effective, and accurate monitoring of peat failures, using feature tracking correlation and DEM differencing (i.e. 4D).

References

Dykes, A.P. and Warburton J. (2007): Mass movements in peat: A formal classification scheme, Geomorphology, vol. 86, pp. 73-93.

Sutikno, S., Sandhyavitri, A., Haidar, M., and Yamamoto K. (2017): Shoreline change analysis of peat soil beach in Bengkalis Island on GIS and RS, International Journal of Engineering and Technology, vol. 9, no.1, pp. 233-238. DOI: 10.7763/IJET.2017.V9.976.

Subekty, A.D. and Neuzil, S.G. (1993): General geology and peat resources of the Siak Kanan and Bengkalis Island peat deposits, Sumatra, Indonesia," in Modern and Ancient Coal-Forming Environments, pp. 45-67.