Bulletin of the Geological Society of Malaysia, Volume 67, June 2019, pp. 21 – 25

DOI : https://doi.org/10.7186/bgsm67201903

Utilization of drone-based photogrammetry for feasibility analysis of potential relocation area in Maleber District, Kuningan Regency, West Java

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Abstract: A landslide in Cipakem Village, Maleber District, Kuningan Regency, West Java has cut off the main access of two isolated hamlets. These two isolated hamlets are located in a hilly steep slope region that is very vulnerable to mass movement processes. To prevent repetitive events that could result in the two hamlets being completely isolated, the government of Kuningan considered the relocation of the 560 impacted families to the potential relocation area in Cikaso Block, Cipakem Village. A feasibility analysis is required to assess whether this area is feasible or not. Drone-based photogrammetry has been utilized to analyse the feasibility of the potential area based on the criteria of settlement area and land suitability. These methods have produced a Digital Elevation Model (DEM) and orthophoto that represent the actual geomorphological and landform features in detail at a relatively low cost. The results showed that the geomorphology of the potential area consists of undulating hills with a dip slope of 10° at the hilltop, and more than 50° at the valley. The hilltop is dominated with shrubbery, while the hillside is dominated by heterogeneous trees, and rain fed rice fields are scattered in the valley. The potential relocation area is located in an area identified as having an intermediate level of vulnerability to landslides. Due to these conditions, the proposed area in the Cikaso Block is considered suitable for relocation under certain technical conditions. However, it does not have enough area to accommodate all of the impacted families.

Keywords: Relocation, landslide, photogrammetry, drone

Abstrak: Gerakan tanah yang terjadi di Desa Cipakem, Kecamatan Maleber, Kabupaten Kuningan, Jawa Barat telah memutus akses jalan menuju dua dusun, membuat kedua dusun tersebut terisolir. Lokasi dusun yang berada di perbukitan dengan kemiringan lereng terjal membuat gerakan tanah pada akses jalan tersebut berpotensi terulang yang akhirnya akan benar-benar mengisolir penduduk di kedua dusun. Oleh karena itu, pemerintah daerah setempat mengajukan lahan di Blok Cikaso, Desa Cipakem, Kecamatan Maleber untuk dikaji kelayakannya sebagai calon lahan relokasi bagi korban gerakan tanah sejumlah 560 KK. Analisis kelayakan berdasarkan kriteria kawasan permukiman dan kesesuaian lahan yang dilakukan dengan memanfaatkan data fotogrametri berbasis *drone*. Metode ini menghasilkan *Digital Elevation Model* (*DEM*) dan *orthophoto* yang menggambarkan keadaan terkini dari geomorfologi serta kondisi fisiografi lahan secara detail dengan biaya relatif murah. Hasil dari pemanfaatan data fotogrametri didapatkan bahwa geomorfologi calon area relokasi di Blok Cikaso berupa perbukitan bergelombang dengan rata-rata kemiringan lereng 10° di bagian puncak dan mencapai lebih dari 50° di bagian lembahnya. Tata guna lahan berupa semak belukar di bagian atas dan hutan campuran dan sawah tadah hujan di lembahnya. Calon lahan relokasi menempati zona kerentanan gerakan tanah rendah hingga menengah. Dengan berbagai kondisi tersebut, maka lahan di Blok Cikaso layak untuk dijadikan lahan relokasi dengan syarat teknis tertentu namun tidak cukup untuk menampung seluruh korban gerakan tanah.

Kata kunci: Relokasi, gerakan tanah, fotogrametri, drone

INTRODUCTION

Heavy rainfall during February 2018 in Kuningan Regency and surroundings areas triggered mass movement events in a number of regions. One of the worst affected areas is the main access to Cigerut Wetan Hamlet and Cigerut Kulon Hamlet, Cipakem Village, Maleber District, Kuningan Regency, West Java. There are four main scarps with several minor scarps alongside the road to both hamlets, as shown in Figure 1 (Lutfi *et al*., 2018). Residents have been isolated as this road is the only access to the hamlets.

Morphologically, the circumstance of both hamlets is undulating hills with dip slopes of up to 60°. According to van Zuidam (1985), this kind of slope is classified as very steep and prone to land denudation. A mass movement area

Figure 1: One of the landslide scarps at the main access to Cigerut Wetan and Cigerut Kulon.

has became the most easily denudated and hence are highly likely to have successive events. It is feared that when rainfall accumulation increases, residents in both hamlets will be completely isolated and even have their lives threatened.

To prevent it, the government of Kuningan Regency through Regional Agency for Disaster Management considered the relocation of 560 impacted families to a safer place. Cikaso Block in Cipakem Village was choosen as the potential relocation area. This is located at coordinate 7° 4' 42.366" S and 108° 33' 50.5044" E or about 1.5 kilometers from Cipakem's capital village. It can be reached by any four wheel vehicles through partially damage paved road or coated with concrete, with a width of 3 meter (Putra *et al*., 2018). This block belongs to a production forest authorized by Perhutani, a government forestry company. They gave 2 of 8 hectares of the whole block for relocation area.

Therefore, a feasibility analysis of Cikaso Block is needed to ensure the relocation plan does not exceed its land carrying capacity. Drone-based photogrammetry was chosen as the analysis method because of its user-friendly and cost efficiency for aerial mapping. Aerial mapping is helpful to figure out the physiographic features of the potential relocation area. The technical guidance for this analysis was made based on these features to create a livable and safe settlement. In the end, the objective of the analysis that is to determine the feasibility of the potential relocation area, will be achieved.

METHOD

Settlement relocation

Relocation is a part of the reconstruction phase in Build Back Better principal from United Nations Office for Disaster Risk Reduction (UNISDR) (United Nations General Assembly, 2016 op.cit. UNISDR, 2017). Reconstruction is the medium and long term sustainable restoration of resilient critical infrastructures, services, housing, facilities and livelihood required for a full functioning community or a society affected by a disaster, aligning with the principles of sustainable development and "build back better", to avoid or reduce future disaster risk (United Nations General Assembly, 2016 op cit. UNISDR, 2017). A habitable relocation area must be considered to ensure the community has access to livelihoods, social network, and marketplace. It is important to guarantee human welfare and sustainability of communities in the future.

Determination of the potential relocation area will be carried out based on the settlements criteria and land suitability as outlined by the National Laws and Regulation of the Minister of Public Works. Law Number (No.) 1 of 2011 mention that settlements are part of the environment outside conservation areas, both in the form urban and rural areas that function as neighborhoods or residential environment and places of activities that support livelihoods. Based on the Regulation of the Minister of Public Works Number 41 of 2007 on Technical Criterias Manual for Cultivations, criteria of settlements and its land suitability are:

1. Topographic relief is flat to undulating (slope between 0 – 25%)
2. Both groundwater and waterworks as a water source are sufficient. Water supply for Municipal Waterworks between 60 – 100 litter/person/day
3. Outside vulnerable hazard zone (mass movement, floods, erosion, abrasion)
4. Well or intermediate drainage system
5. Avoid flood plain/beach/lake/dam/springs/irigation/ railroad and inside flight safe area
6. Exclude the conservation area
7. Not disturbing cultivation or supporting area
8. Avoid technical irigation rice field

A relocation area and the quality of the area are important factors in relocation planning. They are very important for the sustainability aspect of the relocation, such as security from the same disaster; facility to marketplace; social networking; jobs; and industry (Permana *et al*., 2017). The relocation area will accomodate a significant number of people (in this case is 560 families), then it should be considered to be proportional to the existing occupancy of settlements. The Regulation of the Minister of Public Works Number 41 of 2007 requires proportional occupancy about 40% - 60% from total area large, and could change a specific place depending on the local feature and carrying capacity of the land. In this case, we should also take notice of the suceptibility of landsliding in the potential relocation area.

Photogrammetry

Photogrammetry has been defined by the American Society for Photogrammetry and Remote Sensing (ASPRS) as the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena (ASPRS n.d.). Recently, this method has been widely used for aerial mapping taken from an aerial vehicle to identify and

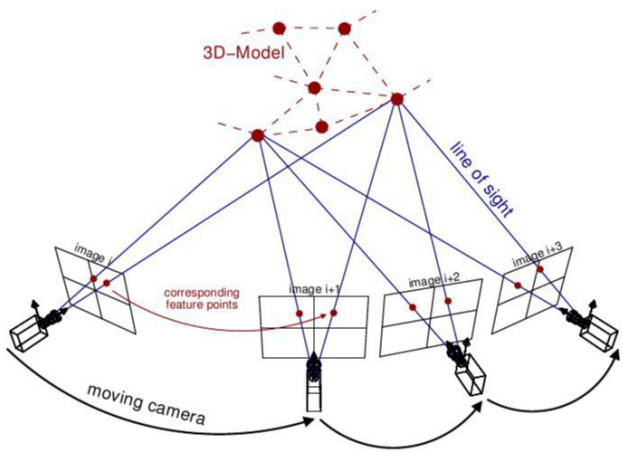

Figure 2: The illustration of photogrammetry method to create a 3-D model of an object from several images at different angles.

analyze a specific area. The principal of photogrammetry as shown in Figure 2 is utilizing two or more overlapping aerial photos to create 3-D images (Minarno *et al*., 2016).

Using photogrammetric, it is possible to produce Digital Elevation Model (DEM) and orthophoto with relatively high resolution quality. For example, a 14 megapixels camera is enough to create an accurate DEM with resolution up to 20 centimeters (Heriwaseso *et al*., 2016). This DEM, however, includes vegetation and artificial object on the surface (building, tower, etc). This kind of DEM is called Digital Surface Model (DSM), and not a terrain condition with vegetation and artificial objects deleted.

Drone-based photogrammetry means photogrammetric measurement platform, which operates remotely controlled, semi-autonomously or autonomously, without a pilot sitting in the vehicle or unmanned aerial vehicle (UAV) or drone (Eisenbeiss, 2009). For detail study area, this method is more efficient and relatively lower cost compared to using an aeroplane based LIDAR system. All kinds of drones are capable for taking photogrammetry image as long as they are equipped with a high resolution camera. Chosing the type of UAV is very important due to the fact that every drone has a different take off and landing operation. For this analysis, the needs required from the topographic study area and the accessibility for drone mobilization must be considered before choosing the type of UAV for the study.

Aerial photos taken from a drone are then processed using computer software e.g. Agisoft Photoscan 1.2. The Orthophoto created from the drone imagery is an aerial photograph that has georeference data, thus it can also be used for further applications and analysis in geological or infrastructure planning, including feasibility analysis of the potential relocation area in Cikaso Block, Cipakem Village, Maleber District, Kuningan Regency, West Java.

RESULT

Photogrammetry data

The DJI Mavic Pro, the quadcopter drone, was chosen for taking aerial photograph in Cikaso Block. This drone has the advantages of being light weight, easy to handle, user friendly and no need for large area for take off and landing, making it quite compatible for taking photogrammetry data in this forest block. It flies at 100 meters altitude from take off position, taking 96 photos with 26.5 hectares coverage.

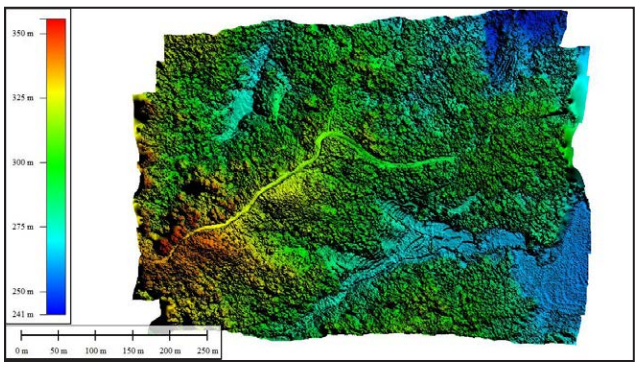

Figure 3: Digital Elevation Model (DEM) of area of interest.

The data collected was then processed using Agisoft Photoscan, one of the most advanced software for UAV data processing. Aligning all of photos is the first thing to do. This rearranges the imagery in a sequencial order according to its position taken. From the aligned photos, a point cloud elevation points are built, which are a set of data points in a coordinate system. A DEM is then created from dense point cloud processing are shown in Figure 3.

The DEM is the data used for creating the Orthophoto model of Cikaso Block. It is saved as a georeferenced raster image for further analysis in ArcGIS (Figure 4) or even in Google Earth application. By overlapping it with Google Earth image, we can see how the block's condition from time to time has changed, making it possible to identify land conversion and paleo-landslides around the potential relocation area.

Geomorphology

The Cikaso Block is mostly covered by thick trees, which makes the topography difficult to desire in the DEM that resulted from photogrammetrical. Elevational contour from the Topographical Map of Lebakwangi Sheet 1308-533 (Bakosurtanal, 2000) are added to reflect the geomorphology of Cikaso Block and surroundings areas clearly. In Agisoft Photoscan, we can also see a 3-D view from Cikaso Block as shown in Figure 5.

Based on the contour line and 3-D view, it is possible to geomorphologically interprete that the Cikaso Block lies on

Figure 4: Georeferenced raster image for advanced spatial analysis.

Figure 5: 3-D model of area of interest for geomorphological analysis.

southwest-northeast ridge on an undulating hill region. The top of the ridge has a 10° average slope while at the edge it has more than 50°. Intermitten springs from the bottom of this curving slope fills the V-shape valley in Cikaso Block as a part of Cisrigading tributary.

Land use and public facilities

All of the trees in the Cikaso Block are part of a production forest that belongs to Perhutani. From a total of 8 hectares, 2 hectares have been granted to the village government to be used as a relocation site. As a production forest, trees are dominating in this block. Photogrammetry data showed most of them are located at the hillside and the ridge slope. Heterogenic small plants are more common at the top of the ridge, flanking the main and only access road to the vicinity of the village. In the valley, rain fed fields dominate land use form a terassering alongside the intermitten stream at the bottom.

No drainage system facilities is identified from the orthophoto. Surface run off seems freely flowing down the slope following the relief or the road. An electricity network is installed and follows the road, electrifying other hamlets in the western part of Cikaso Block.

Mass movement potential

Photogrammetry data have not shown any paleo-landslide traces or any signs of mass movement in the Cikaso Block. The resolution of this image should be high enough to identify mass movement activity or any preliminary sign of landslide activity, such as oblique trees or cracks at the grounds. The absence of those features indicate that landslide activity has never happened in this block or if they did happen, it was a long time ago and the impact is no longer visible.

Additional imagery from the Google Earth image was looked of for a wider image. From this imagery a scarp was clearly visible on the southeastern part of the ridge or western side of the potential relocation area, outside the orthophoto boundary (Figure 6). By browsing the Google Earth historical image, we conclude that this landslide occured around 2016. This evidence indicates that mass movement on this ridge have taken place in the past.

Figure 6: Overlapping photogrammetry image and Google Earth image has revealed the trace of an old landslide around the area of interest.

This is confirmed by the fact that Cikaso Block was included in a Moderate Landslide Susceptibility Zone (Center of Volcanology and Geological Hazard Mitigation, 2009). This suggests that Cikaso Block has moderate susceptibility to landslide. As a result, landslide may occur in this zone, especially along the river side, scarp, cuts road, or areas that are disturbed on the slope. Old landslide may reactivate especially when triggered by high rainfall accumulations, earthquakes, and strong erosional process.

DISCUSSION

Land carrying capacity

Based on the results, the topographic of potential relocation area in Cikaso Block is too steep as a settlement area. Narrow areas at the top of the ridge are the only compatible places in topographic terms. For this land of 2 hectares large, the settlements are recommended to be developed alongside the existing road as the main access. Sloping area in the southern part of the road are available to accomodate a number of homes. A buffer zone should be placed between the residences and the steep slope at the flank to prevent the slope disturbing such as overburdening or cutting. This means that the 2 hectares cannot be optimized for settlements and is not sufficient to accomodate 560 families.

A number of small springs have been identified around the potential relocation area, but are not sufficient as the main source due to their intermitten flow. To supply water, the government of the village plans to use Cikaso's main spring in the mountains. This spring has also become a source of water for other hamlets around potential relocation area. Piping systems are needed to flow the water from the springs since its location is quite far from prospective area.

Susceptibility state

One thing we must consider before using this area as a relocation site is its susceptibility state from hazards, especially mass movement or landslide. This area is considered as a Moderate Landslide Susceptibility Zone that will increase to a High Zone in the rainy season. The development of a settlement or construction in the moderate susceptibility area needs detail slope stability investigations (Center of Volcanology and Geological Hazard Mitigation, 2009).

The previous landslide and existing scarp indicate the possibility of mass movement events in this block. The scarp mentioned before showing the shallow type of mass movement involving weathering soil with a fast movement that could be triggered by heavy rainfall.

The presence of historical landslides and steep slopes are included in the criteria of landslide susceptibility for the area in the Regulation of The Minister of Public Works Number 22 of 2007. Those criterias are:

1. Slope between 15% - 70% (12° - 30°)
2. Heavy rainfall level (more than 2500 mm/years)
3. Thickeness of overburden soil as slope materials are more than 2 meters

4. The rocks has intensive discontinuity or fracturing
5. Fault zone influence area
6. Landslides are identified
7. Less of vegetation or unsupported land covering

The difficulty of planning in a landslide susceptibility areas are that the complexity of the type of landslides occuring and the difference of landslide potential within rocks/soils (Noor, 2011).

CONCLUSION

- Topography of the potential relocation area is undulating hills with an average slope of 10° at the top but more than 50° at the flanks
- The village government needs to search additional area since the potential relocation area is not sufficient for all of the relocated families
- The facilities are available and worthy, but a drainage system would need to be added
- The potential relocation area in Cikaso Block is feasible for a relocation site alongside settlements shape and avoid the ridge side.
- The development of residences should follow technical requirements, including preventative slope engineering principals to prevent any form of mass movements in the future.
- The potential area is located in a landslide susceptibility area, which needs further detailed slope instability analysis and investigation.

ACKNOWLEDGEMENTS

The authors thank the Regional Agency for Disaster Management of Kuningan Regency and the government of Cipakem Village in sharing information and their support during field data collection. Thanks are expressed to Kibar M. Suryadana as drone's pilot and helping in the data processing, to Yunara D. Triana for his help in coordinating with local government and to Sumaryono as the Head of Western Region Landslide Sub Division, for supporting this project.

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Manuscript received 11 October 2018
Revised manuscript received 31 January 2019
Manuscript accepted 2 February 2019