UNMANNED AERIAL SYSTEM FOR CATTLE FARMLAND USE MAPPING: AN OVERVIEW OF PTH ULU LEPAR, PAHANG

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ABSTRACT. The importance of visualizing and overviewing land use and land cover changes will provide beneficial information on current state in order to assist decision making process for farm managers and policy makers. This study aims to access the ability of intermediate commercial quadcopter drones used for land cover mapping and to evaluate the quality and detailed orthomosaics produced for DVS nucleus livestock farm, PTH Ulu Lepar in Gambang. DJI Phantom 4 Pro V2 drone was used to collect digital images. The flight altitute was selected to be at a 120 m, and minimum of 65 % side lap and 75 % front lap to conduct the imaging of an area of 1,229.9 ha. A total of 55 GCPs were used for the georeferencing and check points for accuracy assessment. Agisoft Photoscan v.1.5.5 software was used to generate orthophoto mosaic from 26,617 images captured at 12 cm/pixel resolution. The obtained results showed that the accuracy (RMSE) for longitude and latitude were 2.31 m and 2.81 m respectively, demonstrating that UAS technology provides promising opportunities to create high-resolution as well as highly accurate orthophotos, thus facilitating map creation and updating. The technology also offers a low-cost operational requirement as compared with satellite imagery, does not demand too many and the mobility aspect of the drone can benefit any objective oriented mission to be done at any time under difference circumstances with minimal risk. Future study is suggested to assess the results of the area for more objects from the land cover for crop health, livestock observation and movements.

Keywords: UAS, farm management, land use, orthomosaics

INTRODUCTION

Land use mapping is an approach that has been used to assist farm managers to achieve a better understanding of their managerial land areas. The importance of land use maps is to have a clear-cut understanding in monitoring human-environmental interactions such as elevation, ecological changes and infrastructure development (Yang *et al*., 2017). *Pusat Ternakan Haiwan* (PTH) Ulu Lepar functions as part of the Department Veterinary Services (DVS) nucleus farm for Nelore and Brahman cattle breed. This vast farm area plays a vital role in assuring sustainable cattle production for the use of cattle farmers throughout the whole country. Thus, it is important to have an accurate and objective evaluation of cattle farm land use and land cover (LULC) changes to assist in a proper managerial decision to optimize farm management cost and production. The current method of overviewing land areas is through the use of free access available satellite imagery software including Google Earth, Mapbox and Open Street Map. However, one of the drawbacks is certain available imagery is outdated and some may have low resolution imagery. Besides that, conventional maps that are drawn on papers portraying the estimated farm managerial area are still being used for reference. The advancement of Remote Sensing (RS) technology and image analytics through the establishment of Unmanned Aerial System (UAS), especially the quadcopter drones offer an applicable, economic, and fast technique in aerial monitoring of vast land areas as an alternative to conventional approaches (Matese *et al*., 2015). This technology has the ability to produce higher spatial resolution aerial imagery with minimal cost (Mullerova *et al*., 2017). Another advantage of this technology is its ability to be used in accessing physically inaccessible areas due to geographical factors such as terran and ravine areas. Basically, UAS is aided by Global Positioning System (GPS) as well as Inertial Measurement Unit (IMU) and autopilot systems which enable airborne photogrammetric images and full motion video capturing to be easily done via smooth flight mission (Yao *et al*., 2019). Apart from that, the integration of Geographic Information System (GIS) offers multiple analysis techniques for detailed LULC features and changes for environmental impact assessment (Iizuka *et al*., 2018).

Various studies have demonstrated the usefulness of UAS technology in many different fields. For example, research done by Luna and Lobo (2016) on the utilization of UAS for assessment of crop planting quality by mapping the gaps in the crop canopy is used as a guideline for replanting purposes. Other than that, a study by Jumaat *et al*. (2018) on the usage of high resolution UAS imagery to assess land cover changes in slopes area in Cameron Highland, Malaysia is aimed to be used for future developmental plans for high terrain areas. The advantages of UAS photogrammetry in comparison to conventional field surveying are its ability to produce higher quality and reliability of spatial products, more diversity and user-friendly spatial analytics, ability to speed up the mapping process, more reasonable operational cost, fewer interruptions in operations, and more accessibility to rough areas (Saadatseresht *et al*., 2015).

The objectives of this study are to access the ability of intermediate commercial quadcopter drones used for land cover mapping and to evaluate the quality and detailed orthomosaics produced using a UAS approach.

MATERIALS AND METHOD

Study Area

The study was carried out at Ulu Lepar, which is located in Gambang, Pahang, in the east coast prairie of peninsular Malaysia. The geographical coordinates are 3.717580 ° latitude and 103.010036 ° longitude. It covers an area of 935.5 ha mainly with multiple pasture paddock comprising *Brachiaria humidicola* grass species which are utilized by Nelore and Brahman cattle breed in a free grazing system. Generally, the area contains many different landscape features including farm roads, water bodies, and areas of different variabilities of vegetation with a large topographic variation.

Site Reconnaissance and Pre-Flights Planning

A reconnaissance process was done on site to evaluate and identify suitable locations for the establishment of ground control points (GCPs), as well as to prepare a working flight plan for UAS landing and take-off. A total of 55 GCPs were obtained in this study for geo-referencing and accuracy assessment which comprise 0.4 m^2 white square paper sheets markers, natural or existing features such as building edges, waterbodies and road tracks. Most of the GCPs were placed in the overlap zone of the surveyed grid area depending on the accessability and topographical feature of the area. Next, precise coordinates of all the GCPs were determined in a defined spatial reference frame to ensure geometric calibration (Daramola *et al*., 2017) using Trimble Juno SC handheld GPS.

Flights and image capture

Data were collected for the study by a series of UAV flights. This was accomplished using a DJI Phantom 4 Pro V2 drone attached with DJI FC330 CMOS camera. Flight control, image collection planning and control were carried out using smartphone Drone Deploy application. Images were captured at a flight height of 120 m above ground level from the point of launch with a 12 cm/pixel resolution. This is in accordance with the maximum altitude allowed by the Civil Aviation Authority of Malaysia (CAAM) regulation (CAAM UAS, 2019). During each flight, RGB images were also collected every one second interval at a flight speed of 30 km/h. All flights were designed to target at least 65 % side lap and 75 % overlap (Ajayi *et al*., 2018). Phantom 4 Pro is powered by a 5870 mAh battery pack with a durable flight time of approximately 20-30 minutes from landing to take-off, depending on current wind speed and designated flight plan. Thus, to ensure smooth mission, six battery sets were used for this study. A fresh battery pack was replaced at every set home point during the flight mission. Changes in weather conditions and strong winds were closely monitored to ensure smooth flight and quality data acquisition. The flight mission was carried out in March 2021 and aerial photographs were captured in clear and dry weather. All flights were conducted remotely by one drone pilot and one assisstant as a spotter to monitor the drone flight route.

Image processing and analysis

Imagery quality assessments were done using Agisoft Photoscan v.1.5.5 for all collected images where detection of overlapped and low-quality images (< 0.8) was corrected. All collected images underwent a post-processed correction in ArcMap v.10.8 to increase the positional accuracy of the RGB images. After positional corrections, aligned and high spatial resolution multispectral and RGB orthomosaics were constructed using Agisoft Photoscan v.1.5.5 (Abidin *et al*., 2018). Individual orthomosaics were then mosaiced, digitized and spatially analyzed using ArcGIS version 10.8 to build the final map. All processing software was installed on an HP Prodesk desktop with the following configuration properties; 16 GB RAM, Intel® Core™ i7-8700 Gen CPU @ 3.20 GHz processor, Intel® UHD Graphics 630, 64Bits Windows 10 Pro operating system and 500 GB hard drive disk.

RESULTS AND DISCUSSION

Flight Mission

Planning for the flight mission of the study area is the most important part of the overall study considering personnel, drone safety and regulative issue. For example, in Malaysia under the CAAM for UAS operative law requires that pilot and observer must have a visual line of sight (VLOS) with the drone. This is to ensure that the pilot is in control of the drone for any unexpected occurrence of possible drone signal loss and to notice any potential threat such as birds from colliding the drone. Besides that, the maximum flight altitude is 120 m under the stated CAAM rule (ref). As seen in Figure 1, multiple individual grids were produced for every flight mission where each grid comprises 120 to 300 acres of area coverage. All individual grids were arranged in an overlapped manner to make sure data collection can be optimized. The execution of the overall fight mission took 20 hour and 32 minutes to cover the whole farm area with the use of a total of 83 sets of rechargeable battery packs.

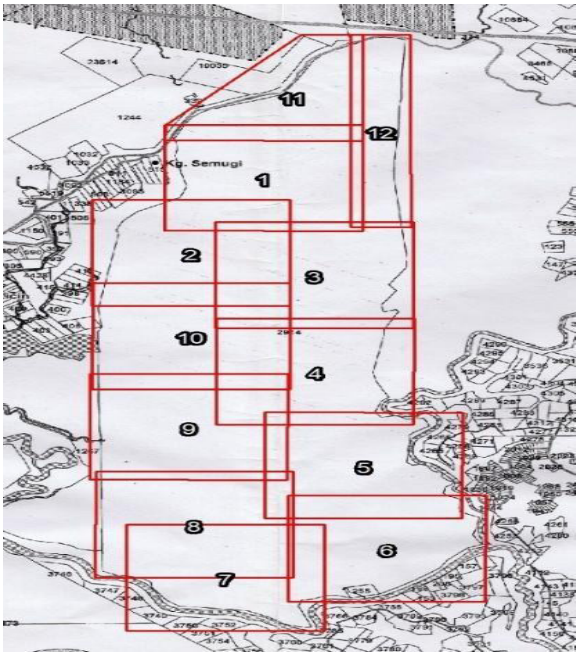
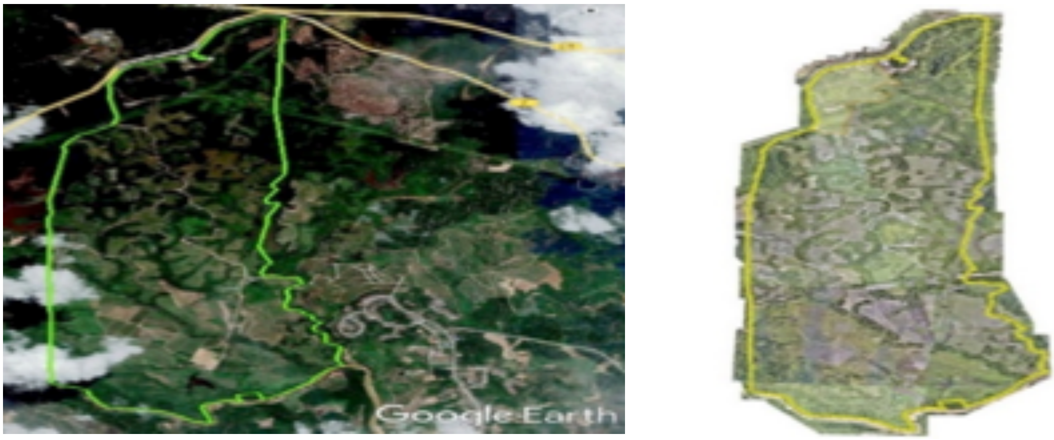


Figure 1. Overlayed 12 individual grid set for the flight mission on the JUPEM cadaster map of PTH Ulu Lepar.

Orthomosaics

Orthomosaic is a large high quality map imagery with high resolution generated from a series of composition of 2D geometrically oriented aerial images. Figure 2 shows the complete orthomosaics comprising a total number of 26,617 images captured consisting of 12 individual set mission grids which covered a total of 1,220.9 Ha area. From the image, it is proven that the use of UAS technology can offer clear high resolution real-time imagery to compare with satellite imagery where cloud cover could be detrimental as shown in Figure 3. This cloud cover makes it difficult or impossible to analyze beneficial information of that particular land surface under the clouds. Although satellite imagery such as Quickbird, GeoEye, World View, and other high-resolution satellite sensors could provide a super high-resolution imagery over a wide area, they may imply certain drawbacks such as cloud cover, higher purchasing cost per image and disability to provide real-time imagery due to the earth orbital circulation which affects satellites image capturing time (Iizuka *et al*., 2018). Therefore, UAS technology is highly reliable and effective to be used to overcome these challenges especially in tropical country like Malaysia that has so much cloud cover throughout the year (Jumaat *et al*., 2018).



(a) (b)

Figure 2. An overview orthomosaics imagery with bounded perimeter of PTH Ulu Lepar, Pahang in comparison with conventional Google Earth imagery dated 2017 (a) vs UAS imagery dated 2021 (b).

(a) (b)

Figure 3. Occurrence of cloud that covered the imagery from satellite point of view (a) vs clear UAS imagery (b) which caused significant lost in land cover detail.

Accuracy Assessment

Spatial accuracy can be defined as the location of pixel elements in reference to the true location on the face of the earth (Mohammed *et al*., 2013). The use of GPS reader in this study is to assure that GCPs collected can be rectified to the UAS longitude and latitude data collected during flights through the Global Navigation Satellite System (GNSS) on board receiver (Elkhrachy, 2021). Hence, multiple ground targets had been set up for GCPs reference marker including paper sheets markers, natural or existing features such as building edges, waterbodies and road tracks. Horizontal accuracy validation is gained through the analysis of difference in latitude and longitude data error and Root Mean Square Error (RMSE) from the UAS and GPS receiver. Thus, Equation 1 and 2 were used to compute the RMSE value in which the lower value of RMSE corresponds to a lower discrepancy between the two groups of data (Korumaz et al., 2021).

$$RMSE_x = sqrt\, [\sum (X_{gps} - X_{uas})^2 / n\,] \quad (1)$$

Where, X/y_{gps} = Observed values,

X/y_{uas} = Reference values, and

n = Number of observations (2)

Differences between actual and estimated GPS coordinates of GCPs were computed as shown in Table 1. From Table 1, the RMSE value for horizontal accuracy longitude (x) is 2.31 m and latitude (y) is 2.81 m. Although the RMSE value is a bit higher compared with results from studies by Mohammed *et al*. (2013) and Rabiu *et al*. (2014), the map output is still reliable to be used in analysing at a moderate scale resolution as obtained accuracy falls within the acceptable range for planning, designs, and extraction of spatial information according to National Standard for Spatial Data Accuracy (NSSDA) (Daramola *et al*., 2017). This is in due to the maximum reliable accuracy of the GPS receiver model used in this study which is 5 m. Hence, the use of Real Time Kinetic (RTK) GPS receiver and addition of more GCPs can lower the depicted value between the observed and actual position to increase the accuracy of the orthomosaics produced up to sub-meter level of accuracy as reported by Okegbola *et al*. (2020) and Daramola *et al*. (2017). Furthermore, Muhammad *et al*. (2020) found that by lowering the UAS flight altitude to 80 m and increasing the overlap to 70 % as well as the side lap to 50 % may also help in getting better accuracy.

Table 1. Differences between GPS and UAS post-processed GCPs coordinates.

Point	▲X(m)	▲Y(m)	Point	▲X(m)	▲Y(m)
1	-4.23	2.22	29	2.28	-2.82
2	0.14	2.78	30	-0.37	-2.28
3	-2.64	-6.35	31	3.07	-2.55
4	6.55	-0.79	32	-0.10	-0.96
5	1.00	-7.55	33	0.96	-2.55
6	-1.38	1.85	34	1.49	-2.02
7	-2.60	-6.16	35	-0.10	-1.50
8	0.84	-0.49	36	0.96	-0.44
9	-2.64	-0.54	37	0.30	-2.68
10	1.72	-0.15	38	-1.82	-2.15
11	-2.77	2.90	39	-0.37	1.55
12	0.53	4.75	40	-0.10	-1.36
13	-1.98	0.39	41	-1.43	-1.36
14	3.84	1.84	42	1.22	1.29
15	0.53	1.18	43	3.87	-1.36

16	-1.98	0.39	44	3.87	-1.36
17	3.31	-5.44	45	1.22	1.28
18	0.16	-3.22	46	1.22	-4.01
19	2.01	-2.94	47	3.87	1.29
20	2.02	-4.01	48	1.22	1.29
21	2.81	-1.36	49	1.22	-4.01
22	1.48	-1.09	50	1.22	1.29
23	2.54	-4.80	51	3.87	1.28
24	3.34	-0.96	52	3.87	-1.36
25	0.69	-4.93	53	1.22	-4.01
26	0.69	-1.23	54	-1.42	-1.36
27	0.16	-1.23	55	3.87	1.29
28	0.16	-2.81	RMSE*xy*	2.31	2.81

Visual Analysis

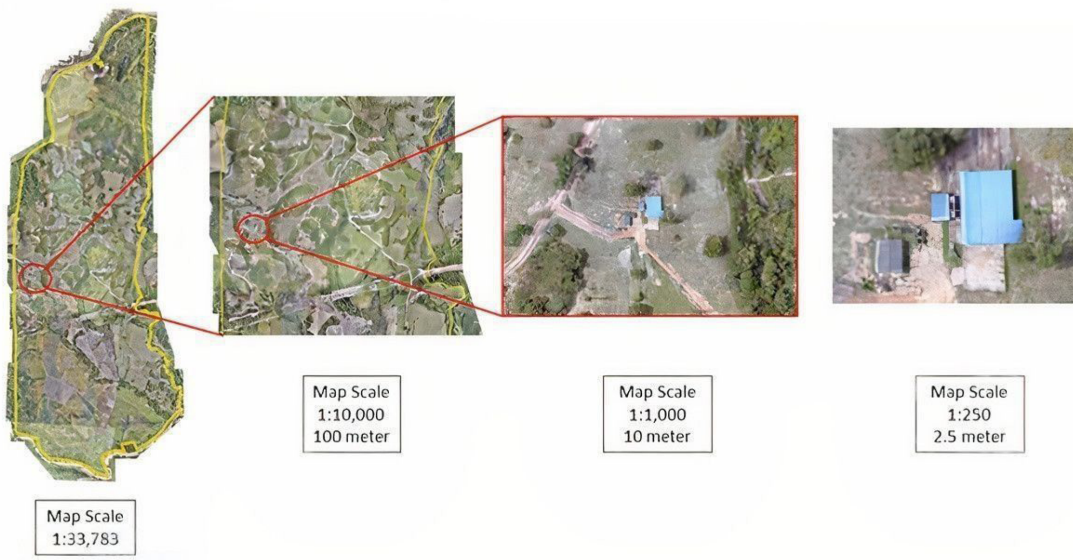


Figure 4. Different imagery resolutions at different map scale.

Figure 4 shows the exact resolution of the orthomosaics as the detail properties can be represented clearly (maximum) at 2.5 m resolution. At this level, the detailed structure and properties of a given farm infrastructure can be defined clearly (Figure 5). For the purpose of this study, the required resolution is considered at 100 m altitude (1:10,000) based on the management needs in overviewing the boundary area of the farm properties and topography measurements.

According to Budiharto *et al*. (2021), generally low altitude mapping (40 m) will produce better accuracy compared with above 80 m altitude due to the principle of accuracy being directly proportional with resolution.

Study reported by Colomina and Molina (2014) also showed that the lower the flight altitude, higher level of unprecedented level of detail images can be captured by the UAS which produce higher opportunity of high resolution mapping. However, although lower altitude provides higher resolution data, the result may be limited to lower coverage area and time consuming to compare with higher altitude mapping. Through the availability of super high-resolution imagery produced, classification of LULC changes can be computed such as exact paddock acreage (Figure 6). This can be beneficial in determining available stocking rates for cattle feeding and managing appropriate soil pasture fertility programme.

Figure 5. Parts of orthomosaics where water bodies and infrastructure can be clearly identified at 1:800 map scale.

Figure 6. Classification of actual paddock area for livestock consumption.

Furthermore, performing vegetation monitoring can be done through the generated visible band Red Green Blue (R:G:B) imagery by incorporating certain vegetation indices such as the Visible Atmospherically Resistant Index (VARI), Green Leaf Index (GLI) and Visible Atmospherically Resistant Indices Green (VIgreen) (Eng *et al*., 2019). VARI index is mostly dependent on leaf-area biomass (Starý *et al*., 2020). Equation 3 is used to estimate the fraction of vegetation with a minimal sensitivity to atmospheric effects (Gitelson *et al*., 2002).

$$VARI = \frac{(Green - Red)}{(Green + Red - Blue)} \quad (3)$$

Figure 7 depicts the single band RGB composite based on VARI used as an example in this study. The darker green ($r^2 = 0.31$) area shows higher vegetation canopy area whereas the darker red ($r^2 = 0$) indicates areas with less to zero vegetation presence including bare soil. This may alert the farm manager that the particular paddock area is not productive enough, hence managerial decision can be made to plan for reseeding and renovation work. However, further understanding and ground thruthing work still needs to be done in assuring the precision of the data. This is because certain vegetation index such as VARI can be sensitive to atmospheric effects such as changes in weather at the time when the photogrammetry data were taken (Fernandez *et al*., 2021).

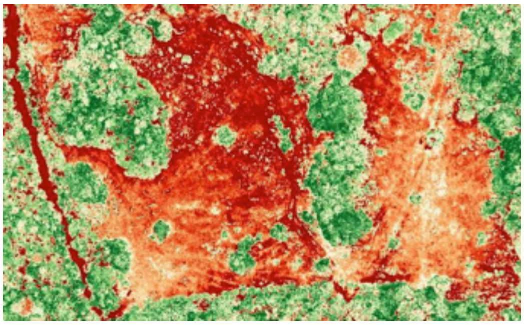



Figure 7. Original data (a) vs single band RGB VARI (b) result from the same paddock area.

Digital Elevation Model (DEM)

DEM is a generated from high-resolution 3D point clouds from a photogrammetric software which can be used to identify elevated objects such as buildings, trees, shrubs and sloppy areas. Kalantar *et al*. (2018) previously reported that the accuracy of the orthomosaics can be significantly increased through the use of DEM and the use of very high-resolution image drone data. Figure 8 shows the DEM output of the study site where different height range can be depicted by different colours. The lowest flat area is 26 m and the highest peak area is 99.4 m above mean sea level (AMSL). Through this data, managerial planning and decision can be made accurately for future area development such as new paddock, farm road network and infrastructure establishment.

Applicability of Low-Cost UAS

Through this study, the usage of low-cost quadcopter drone with the integration of GIS

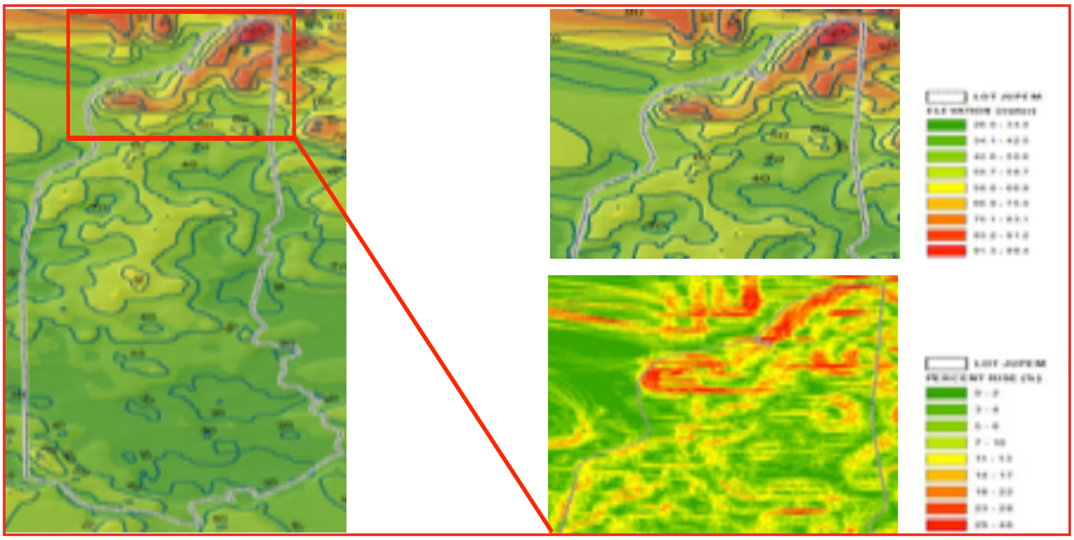


Figure 8. DEM analysis on slope and terrain area of interests

and imagery processing software offers an innovative alternative approach for acquisition of high-resolution aerial imagery over small, mid-sized and large areas when compared to conventional acquisition of aerial images by airplanes or satellite which requires a more elaborated and long-term scheduling by specialized operating personnel that is also expensive. Furthermore, airplanes and satellite imagery approach are restricted to only large areas (50-100 km^2) with much lower temporal repetition rates (Lehmann *et al*., 2017) whereas by using a drone, small plotted grids (0.01 km^2) can be easily planned as it requires only short period of flight time to finish with minimal cost implication. Besides that, the usage of this technology to obtain aerial view assessment for inaccessible and risky areas is more user friendly compared with conventional method. This results to higher competence in area inspection as the risk of working in an unsafe condition is lowered (Giordan *et al*., 2020). However, a certain degree of drawback has been identified during this study including the dependency of UAS to its battery pack capacity which may limit significant flight time. Other than that, topography effects on the stability of the drone GPS signal connection may be disrupted multiple times during flight time which cause several unsuccessful aerial photogrammetry missions. Also, these missions are dependent on weather condition (Vélez-Nicolás *et al*., 2021).

CONCLUSION

As a conclusion, this study has demonstrated the usage of UAS in combination with GIS applications for LULC mapping with specific emphasis on cattle farm land overview as a decision support system tools in making detrimental managerial decision. The technology has shown promising result that the UAS, albeit being a comparatively low-cost technology is robust enough to produce high resolution imagery which can further be processed for different spatial analysis including plant health assessment, topography classification and real time observation on temporal changes. Overall orthomosaics accuracy and visual quality obtained is acceptable, in comparison with conventional terrestrial surveying approaches, airplane and satellite imagery data, which are more expensive and costly. The technology also offers a low-cost operational requirement as compared with satellite imagery, does not demand too many and the mobility aspect of the drone can benefit any objective oriented mission to be done at any time under difference circumstances with minimal risk. For future study, the potential of UAS technology can be further expanded with the integration of different sensors such as the Near Infra-Red (NIR) and thermal sensor for a more detail observation of crop health and diversity, animal observation as well as tracking animal movements in farms.

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