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Research Article

Study of the Accuracy of Sri Lankan Drone Survey Technology for Land Survey on Different Terrain Conditions

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Abstract With the development of the technology, Unmanned Aerial Vehicles (UAVs) are more prominently used in construction field for surveying. Because of low time consume and easy to get data at unreachable places also. At present, large scaling topographic maps are obtaining using unmanned aerial vehicle (UAV) photogrammetry method, therefore UAV photogrammetry has replacing traditional survey method like total station. But don't know how much accuracy it has, with comparing traditional survey methods. The accuracy may be consisting on the terrain conditions. So, it is better to check which terrain conditions have more accurate and which terrains are in very low accuracy. And also, accuracy of results may be depending on the accuracy of the topography software. Level terrain, vegetation area, build-up area and slope area were obtained during the research. Selected the Kantale sugar factory area in Sri Lanka, to understand the different terrain conditions. The results showed that the UAV results are more accurate with level terrain conditions and accuracy is low with other terrain conditions.

Keywords *Drone survey; Topography; UAV; Total station; RTK*

1. Introduction

The use of drones is rapidly becoming popular across many fields of study, such as engineering, military, agriculture, logistics, journalism, disaster management etc. In the field of surveying, drones are increasingly becoming standard survey tools (Moloney, Hilton, Sirguey, & Simsons-Smith, 2018). Drone surveying employs Unmanned Aerial Vehicle (UAV) based photogrammetry techniques for topographic surveying (Eisenbeiss, 2009). It is seen that that this method of survey is being used in many different environments (Ryan, et al., 2015; Chirayath & Earl, 2016; Casella, et al., 2017) and for varied purposes such as studies on agriculture and forests (Feng, Liu, & Gong, 2015; Honkavaara, et al., 2013), disaster management (Quaritsch, Kruggl, Wischounig-Strucl, Bhattacharya, Shah, & Rinner, 2010) etc. Further, given the cost effectiveness and efficiency of the drone surveying technique its increasing popularity is justified (Mancini, Dubbini, Gatteli, Stechchi, Fabbri, & Gabbianelli, 2013).

Land survey is a field of expertise that has a long history dating back to 1400 B.C. where Egyptians used surveying techniques for taxation of land plots (Root). Land surveying is the measurement and mapping of our surrounding environment using mathematics, equipment and specialized technology. In the recent past, instruments such as the surveying chain, measuring tape, levelling instrument, the odolite were used for this purpose. Since the turn of the century, instruments such as the Total Station (TS), GNSS-RTK (Global Navigation Satellite System–Realtime Kinematic) instruments, LiDAR (light Detection and Ranging) techniques are used for land survey work.

The most commonly used land surveying equipment in Sri Lanka at present are Levelling instruments and Total Station instruments. Even though high precision surveying work can be done using these, they require resource and time intensive techniques to collect data (Mouget & Lucet, 2014). Further, since these instruments are terrestrial equipment, the use of these for surveying is not practical in instances where the terrain is rugged (Barry & Coakley, 2013). Hence, as a solution for issues of practicality and high resource requirement, UAV based surveying has been introduced. Drone surveying is especially convenient when the terrain to be surveyed is large in area, since drones have the ability to carry out data collection with minimum human involvement (Mozas-Calvache & Perez-Garcia, 2017).

A major factor that contributed to the increase in popularity of UAV photogrammetry is the evolution of computer-based algorithms and computation techniques of image processing enabling easier development of digital models (Barba, Barbarella, Di Benedetto, Fiani, Gujski, & Limongiello, 2019). Some advantages the UAV technique has over Terrestrial Laser Scanners (TLS) are, lower instrument cost, higher data collection speed, and better texture of terrain (Barba S. B., 2019). On the other hand UAVs have some disadvantages such as dependence on climatic conditions, limitation in payload, etc. (Pflimlin, 2004; Zongjian, 2008).

UAV sensors have the ability to collect data (images) from two positions. Namely, 'Nadir images', and 'Oblique images'. Nadir images are those collected when the axis of the camera is vertical and Oblique images are collected when the axis of the camera is at a tilt close to 45°. Typically, both nadir images and oblique images are combined to deliver best results in shape definition and continuity of surface (Rossi, 2017). The accuracy of the resultant model is dependent upon certain photogrammetric parameters (Barba S. B., 2019). Of these, the following are most critical,

- The angle formed between equivalent rays in different images. The greater the angle, higher the accuracy (Kraus, 2007).
- The accuracy of Ground Control Points (GCPs). It is seen in literature that accuracy of the GCPs is directly proportional to the accuracy of the model (Agüera-Vega, 2017).

In terms of UAVs, there are two main types. Fixed-Wing UAVs and Multi-Rotor UAVs. Multi-rotor drones are more commonly used since its comparatively easy maneuver. They are easier to fly, take-off, land and perform autonomous flights (Thamm, Breiger, Neitz, Meyer, Jansen, & Monninghof, 2015). Further, they provide more accurate data due to their ability of capturing stable images. On the other hand, fixed-wing drones have the ability to cover larger areas in one flight due to their higher flight endurance but require skilled pilots and suitable landing areas (Boon, Drijfhout, & Tesfamichael, 2017). Factors such as flight time, maintenance and cost are in favour of fixed-wing drones whereas higher data accuracy is achieved through multi-rotor drones.

2. Aim of Study

This study aims to develop Digital Terrain Models (DTMs) using a fixed-wing UAV in diverse terrain conditions (Level, Vegetated, Built-up and Sloped terrains) and compare the results with conventional land surveying techniques in order to understand the accuracy, practicality and usability of UAV photogrammetry techniques in Sri Lanka. An area in Kantale city (8°19'01.7"N, 81°02'40.5"E) in the Trincomalee district of Sri Lanka was selected as the study area. Figure 1 shows the boundary of the survey area.

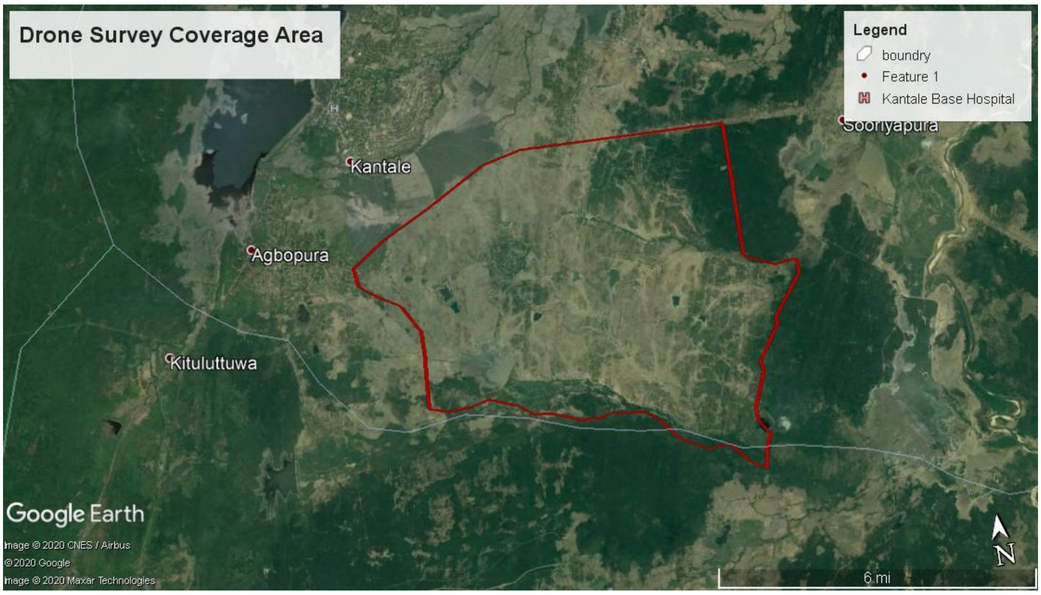

Figure 1: *Boundary line of survey area – Kantale, Sri Lanka (Image courtesy: Google Earth)*

3. Methodology

3.1. Site Preparation and Flight Planning

GCPs were positioned along the boundaries and at midpoints of the survey area as seen in Figure 2. 40 GCPs were spread over the study area of 28 ha. Ground Control Points (GCPs) were established using a NAVCOM SF-3050 GNSS instrument (Accuracy up to ±1 cm + 0.5ppm) utilizing Real Time Kinematic (RTK) correction technique (NavCom Technology, Inc., 2014). The ground control markers consisted of 2feet * 2 feet squire shape white colour wooden board.

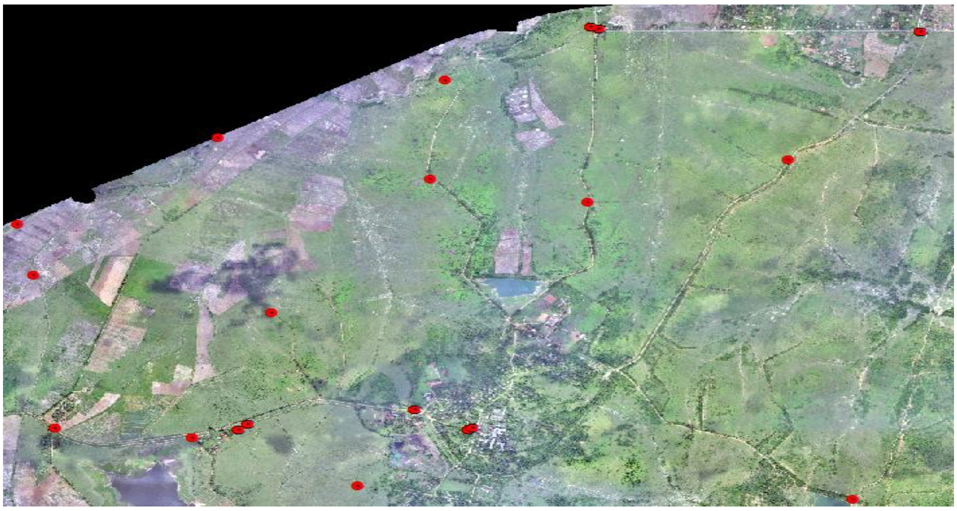

Figure 2: *Ground Control Point locations in the survey area*

For collection of aerial data, a CeyTwin Mapping Drone equipped with RTK GPS tagging, shown in Figure 3 was used. This is a locally developed drone in collaboration with the University of Moratuwa, Sri Lanka (Kandage). The approximate take-off weight of the drone was about 3.5kg. The drone is propelled by two 180W brushless motors and powered by a 14.8V 10,000mAh battery. The CeyTwin Mapping Drone has a flight time of approximately 1 hour and a speed of approximately 20ms^{-1} whilst carrying its payload.

Figure 3: *CeyTwin mapping drone used for data collection [University of Moratuwa]*

A Canon IXUS 160 camera was used for image capturing. Camera specifications are shown in Table 1.

Table 1: *Camera specifications*

Type	Specification
Model	Canon IXUS 160
Megapixels	20
Resolution	5152 x 3864
Sensor size (mm)	6.16 x 4.62

The UAV flight lines were calculated using (PIX4D) with flight lines being spaced apart with 75% forward overlap and 65% side overlap. The flying altitude of the UAV was approximately 400m above the ground level and variation was around 5 m. 191 aerial images were taken keeping the camera axis vertical for increased accuracy at rate of 3 seconds. The flight path taken when capturing data in the level terrain is shown in Figure 4.

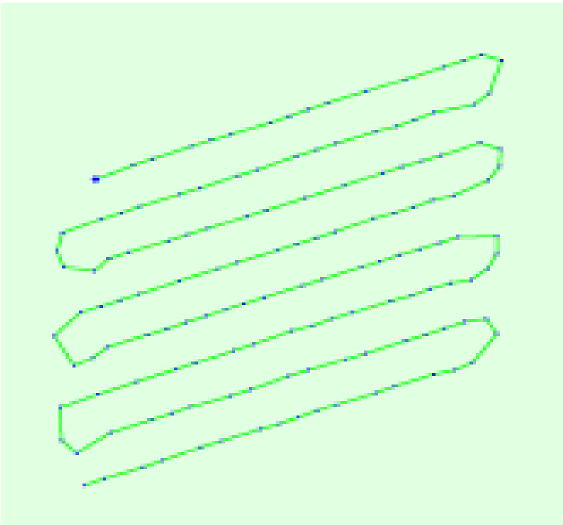

Figure 4: *Flight path*

3.2. Data Acquisition and 3D Point Cloud Generation

The data was collected on a morning (8.30am), in a day with no adverse weather conditions. As observed in Figure 4 the data was collected in one flight in autopilot mode. The Pix4Dmapper photogrammetry software was used for digitization. 428,452 2D key points and 156,120 3D key points were used for bundle block adjustment with a mean projection error of 0.116 pixels. Red and yellow areas indicate low overlap for which poor results may be generated. Green areas indicate an overlap of over 5 images for every pixel. Good quality results will be generated as long as the number of key point matches is also sufficient for these areas. Figure 6 shows developed Digital Terrain Model (DTM) of the area.

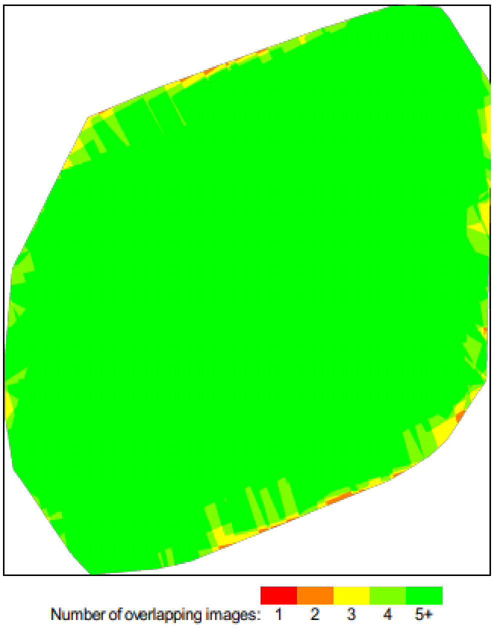

Figure 5: *Overlapping images per pixel in Orthomosaic map*

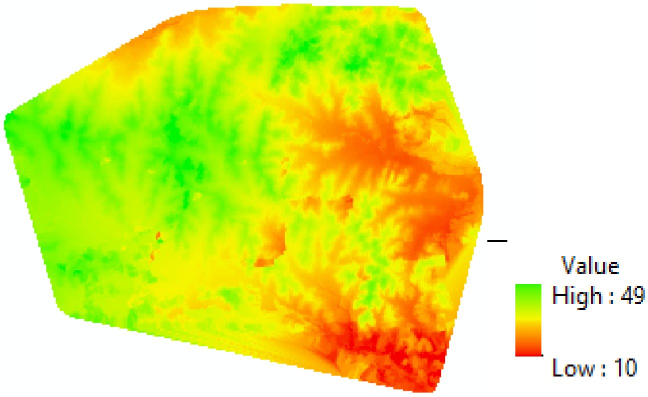

Figure 6: *Digital Terrain Model (DTM) of Area*

3.3. Spot Height Comparison

A SOKKIA CX-102 Total Station (TS) instrument was used to cross-check the DTM developed using UAV photogrammetry. The Total Station instrument was used paired with a standard prism to collect terrain data. The accuracy of the distance measurement of the instrument is $\pm(2 + 2\, ppm\ x\ D)\ mm$ when using 'Fine' measurement observation mode, and the accuracy of angle measurement is 2" within a range of 1.3m to 4000m (TOPCON Corporation). The area was classified based on the terrain condition as Level terrain, Vegetated terrain, Built-up terrain and Sloped terrain.

- Level terrain – Grade less than 5%, open area with no vegetation or structures
- Vegetated terrain – Grade less than 10%, trees covering more than 50% of the area
- Built up terrain – Grade less than 10%, Single storey, two and three storey structures covering approximately 50% of the area

- Sloped terrain – Grade greater than 30%, shrubbery covering the area

Spot heights of these terrains were measured with the TS and projected onto the developed DTM as seen in Figure 7. The difference between the TS elevations and DTM elevations were found and classified by the terrain type. Table 2 presents a summary of the statistical data of the differences in elevation by the terrain type and along the boundary of the DTM. The difference in elevation (error) was calculated using equation 1.

$E = H_{TS} – H_{DTM}$ ---- (1)

Where,
E = Difference in elevation at given location (m)
H_{TS} = Elevation measured using Total Station instrument (m)
H_{DTM} = Elevation from developed Digital Terrain Model (m)

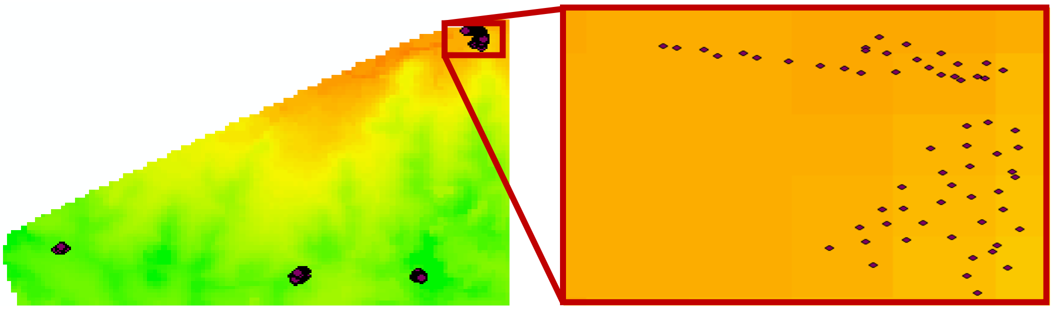

Figure 7: *Projected point clouds on the DTM (left) and projected points (right)*

Table 1: *Statistical data of Elevation differences between TS and DTM Spot Heights (values given in (m))*

Terrain type	Min	Max	Mean	Absolute Mean	RMSE	Standard Error
Level	0.002	0.222	0.001	0.098	0.118	0.017
Vegetated	0.001	1.26	0.315	0.432	0.460	0.065
Built Up	0.271	0.619	-0.418	0.418	0.099	0.023
Sloped	0.022	1.244	0.200	0.650	0.717	0.131
Boundary	3.371	4.799	3.887	3.887	0.260	0.033

4. Discussion of Results

Varying levels of accuracy is observed in each of the terrain types. Of the four terrain types studied, level terrain data has the minimum error spot heights. A mean absolute error of 98mm with an error spread between -0.235m and +0.222m. When considering the vegetated terrain, the error ranged from -0.523m to +1.260m depicting a positive bias in the DTM elevation data. This indicates that the predicted elevation is less than the actual elevation of the point. The variation in error in built up terrain ranges from -0.619m to -0.271m indicating that the TDM elevations are higher than the actual elevations. Sloped terrains showed the largest error in spot heights. The error ranged from -0.992m to +1.245m with a mean absolute error of 650mm. The spread of errors in each terrain condition are graphically represented as histograms in **Figure 8**.

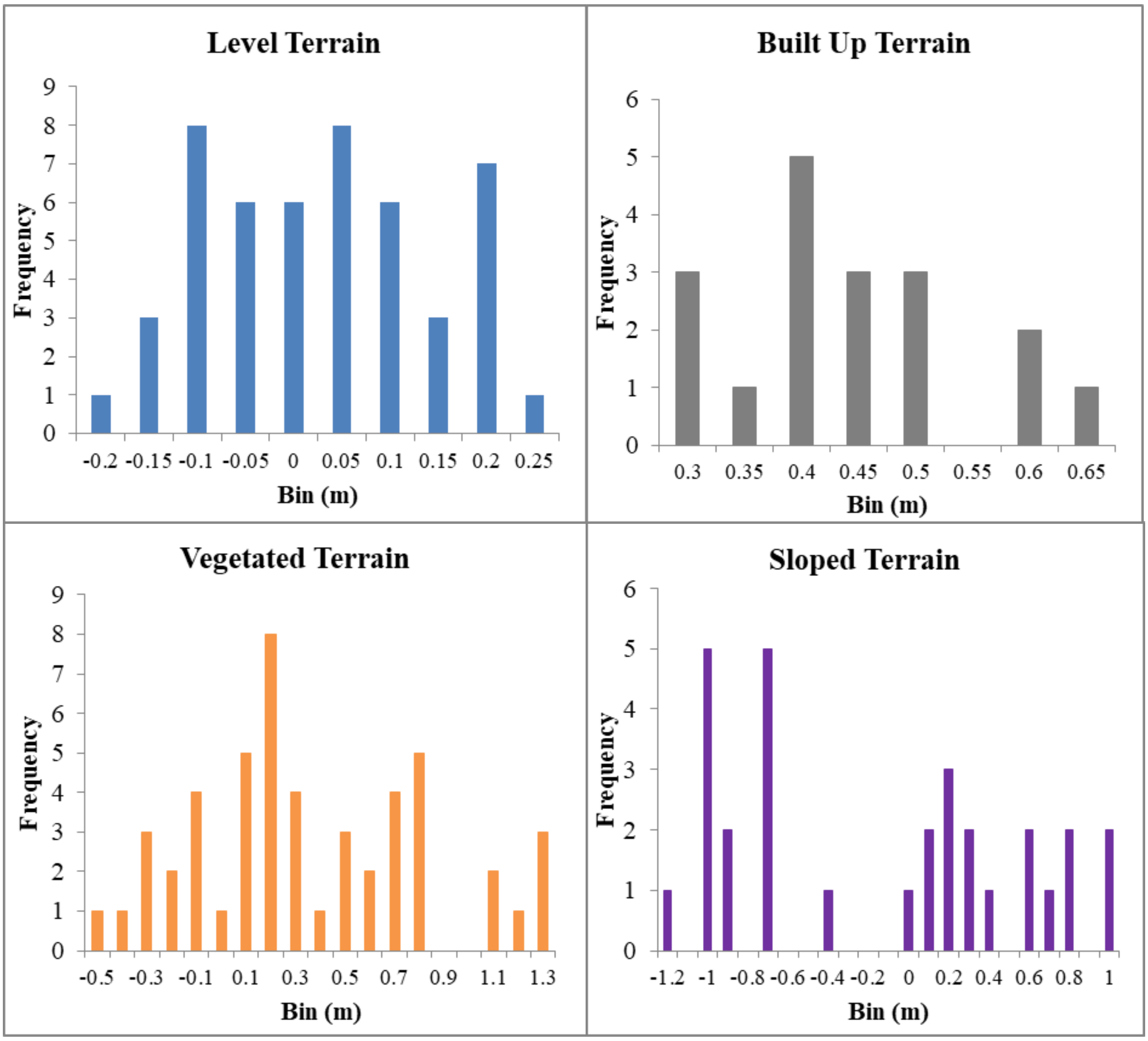

Figure 8: *Elevation difference Histograms of terrains – Level (top left), Built Up (top right), Vegetated (bottom left), and Sloped (bottom right)*

When eliminating buildings from the surface model to get the terrain model at build-up areas, the exact elevation of the terrain after the elimination cannot be found. Therefore, the error is higher in vegetation areas.

Similarly, there are elevation differences in vegetation area due to trees. Elevation of points, where there are trees, are calculated using the elevations of points, where there are no trees. The elevation differences in vegetation area are higher than elevation differences in build-up area. The reason is the ground surface of built up area is more level than vegetation area.

Therefore, the computer process can predict the elevations of eliminated areas more accurately

In the slope area overlap of photographs are very low. Also, the flying height continuously change during the drone survey of a slope area, Therefore the scale is also changed with the flying height, but in the computer analysis we consider a constant scale. It creates a considerable error for slope areas. Due to these two reasons the RMS value for slope area is significantly higher than other ground conditions.

At the boundary of the drone survey, the number of photographs available is very low. Image 5 shows the number of overlapping imagers at every point. At the middle of the area number of imagers overlapping is more than five (5+), but at boundaries, the number of overlapping photographs are lower than three (3). Therefore, the accuracy of the Drone Survey (DTM) is very low and elevation difference is very high due to not achieving required over lapping of the photograph at the boundaries.

Conclusion

DTMs are created at different ground conditions showed various errors when compared with data points acquired by the total station survey.

The errors of mean absolute values and root mean square values are very low in level terrain condition. Therefore, the traditional topographical survey methods can be replaced by modern drone survey technology with a higher degree of accuracy.

Total station survey can be replaced by drone survey method at vegetation and build-up areas, if the ground of that area is level, because in computer processing elevation of areas which are covered by vegetation are considered as the elevation of areas where there is vegetation.

At slope areas, the UAV path is not parallel to the slope. Then the overlapping is decreased at slope areas. Resultant is accuracy of the model being reducing within a slope area. Within a slope area, the overlapping should be increased rather than in level area to get more imagers.

If the survey area is not even, the area should be categorised according to terrain condition and flight parameters should be changed for every ground condition.

The details given in UAV photogrammetric technique have more information and also faster when compared to the total station method.

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