

Utilization of Unmanned Aerial Vehicle (UAV) for Topographic Survey Using Ground Control Points (GCP) from Geodetic GNSS

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Abstract – Mapping with UAVs is a large-scale mapping strategy or method that can shorten the implementation time compared to conventional survey methods that sometimes cannot represent an area as a whole. Aerial photos recorded by drones generally still have a level of position error of up to several meters, so tie points are needed to improve the accuracy of aerial photos. This research aims to utilize drone camera technology to produce geospatial data, both in the form of raster data from aerial photographs and vector data in the form of land contours showing the height of the land surface in Gampong Cot, Gampong Blang, Krueng Kalee, and Angan in Darussalam District, Gampong Durung and Neuheun in Masjid Raya District, Gampong Labuy and Lam Ujong in Baitussalam District. Aerial photo processing produces high-resolution image data of 5 cm/pixel. Ground Control Points (GCPs) are used as tie points to improve the accuracy of aerial imagery. GCP measurements use geodetic GNSS, which has an accuracy of cm to mm. Aerial photos that previously had an error rate of 2-7 meters, after being bound with GCP points, the error rate decreased to below 1 meter. Aerial photographs also show that the land cover in the study area is partly forest. Some areas in the west and north are C excavation mining areas. Based on the contour extraction results, the ground elevation in block 1 (Gampong Durung, Gampong Cot, Gampong Angan, and Gampong Lam Ujong) is 66 to 301 meters, block 2 (Gampong Neuhen) is 50 to 260 meters, and block 3 (Gampong Lam Ujong and Labuy) is 90 to 188 meters.

Keywords: Topographic measurement, UAV, GNSS Geodetic, Contours

Introduction

Topography comes from the Greek word *topos*, which means place, and *grapho*, which means writing. Topography is the natural and artificial appearance of the earth's surface's shape, including differences in height, area shape, slope, and others. A topographic survey is a survey that aims to obtain information about the land surface. The information can be in the form of high and low to the physical condition and position of an object, both natural and man-made, on the land's surface to be mapped. Surveying and mapping techniques develop rapidly along with technological developments. The development of technology related to equipment and the complexity of mapping survey work is increasing every day, one of which is marked by the development of technology to support surveying and mapping activities is unmanned aircraft or generally referred to as Unmanned Aerial Vehicles (UAV).

Mapping with UAV is a strategy or way for large-scale mapping that can reduce operational costs and shorten implementation time compared to conventional survey methods that sometimes cannot fully represent an area. UAVs are vehicles equipped with waveform flight control systems, precision navigation (Ground Positioning System/GPS), and flight control electronics to fly according to flight planning (autopilot). This allows for position and orientation tracking from sensors implemented in local or global coordinate systems (Eisenbeiss, 2009) UAV are usually also equipped with high-resolution camera equipment for capturing aerial photographs.

UAVs can produce imagery with large spatial resolution, display current conditions, and are not constrained by clouds. Through UAVs, the level of data detail becomes very high, and the data collection process becomes easier (Zarco-Tejada, *et al.*, 2014).

To create Digital Elevation Model (DEM) maps or topographic maps, the use of UAV cameras still needs to be widely utilized. UAVs commonly used in mapping are those equipped with LIDAR (Light Detection and Ranging) or Terrestrial Laser Scanning (Ouédraogo, *et al.*, 2014). The technique used to construct DEM data from aerial photography is called photogrammetry. This technique can determine the properties of the geometry of an object obtained. The results of aerial photographs obtained must be overlapped with each other on the same object. The wider the overlapping area, the more accurate the results will be (Rock, *et al.*, 2011) (Sze, *et al.*, 2015).

GNSS is a satellite-based positioning system and augmentation infrastructure that supports navigation, positioning, and timing activities and is always available for 24 hours across the earth's surface (Hofmann-Wellenhof, *et al.*, 2007). The use of GNSS in Indonesia for positioning, surveying, and mapping began around the end of 1988. After that, GNSS expanded to include various fields such as deformation monitoring, geodynamic earth studies, land administration, and transportation (Abidin, 2007). Positioning with GNSS surveys can be done with several methods, including rapid static, stop-and-go, real-time kinematics, and pseudo-kinematics. In some of the methods above, the static method has a fairly high level of accuracy, reaching cm. Research on the RTK method with several satellites has been reviewed (Yuwono, *et al.*, 2017) concluding that the Static method has a smaller lateral distance difference and standard deviation than the Real Time Kinematic (RTK) method. Static methods for positioning have been widely used, among others, for base stations, control frames, deformation studies, monitoring, and stakeout work.

In photogrammetric surveys, it is necessary to perform geometric correction, which aims to rectify or restore the image so that the coordinates match the geographical coordinates (Purwadhi, 2001). The density of the ground control point distribution affects the data accuracy level. Ground control points indicate the position (X and Y) and elevation (Z) coordinates. Ground control points were measured using GNSS Geodetic to obtain high accuracy. Determination of ground control points is also carried out to provide coordinate references to the results of dense point cloud operations so that the former model can improve its geometric quality and produce accurate DEMs and orthophotos. DEM data will be created from upright (vertical) aerial photography data with ground control points using GNSS Geodetic to make high-accuracy images. This research aims to utilize drone camera technology to produce geospatial data, both in the form of raster data from aerial photographs and vector data in the form of land contours showing the height of the land surface in Gampong Cot, Gampong Blang, Krueng Kalee, and Angan in Darussalam District, Gampong Durung and Neuheun in Masjid Raya District, Gampong Labuy and Lam Ujong in Baitussalam District.

Methods

This research uses two tools, namely drones and GNSS Geodetic, as well as two software, namely Agisoft Metashape and ArcGIS. There are two stages in this research, namely the GNSS and UAV stages. Each stage consists of data collection and data processing. The research method and flow chart will be explained as follows.

GCP Data Acquisition using GNSS Geodetic

GCP are points on the earth's surface where image and reference map coordinates can be positioned and identified (Liew, *et al.*, 2012). In addition to GCP (Ground Control Point), there is also the term ICP (Independent Control Point). ICPs or checkpoints are ground control points used to control objects by comparing model coordinates with actual coordinates. The main difference between GCP and ICP is that GCP is used during data processing, while ICP functions when the data is already a product and is not included in the data processing process. This point is used to obtain horizontal accuracy of aerial photography (Lailissaum, 2018). This research only uses GCPs in data processing. Ideally, ground control points are placed evenly in the area to be mapped. Such distribution reduces the influence of errors on geometry correction results (Rehak & Jan, 2016). Ideal locations for GCP positions are street intersections, street corners, areas with striking colors, and objects that are easily identified or known. Trees, buildings, and electricity poles must be avoided because they are challenging to locate and have high similarities (Hasyim & Taufik, 2009). The requirements for determining the distribution of ground control points are as follows (BIG, 2016):

- On the perimeter of the image area

- In the center of the area/scene
- At the border/overlap scene of the image
- Evenly distributed within the image area
- Adjust to terrain conditions

In this study, a 50 x 200 cm pre-mark (ground control point marking) was used, which was made in the form of a cross with the pre-mark point located right at the intersection of the marks. The color of the pre-mark was chosen with striking color and different from the surrounding conditions so that it was visible during the processing of aerial photos in Agisoft Metashape.



Figure 1. GCP Measurement in Area

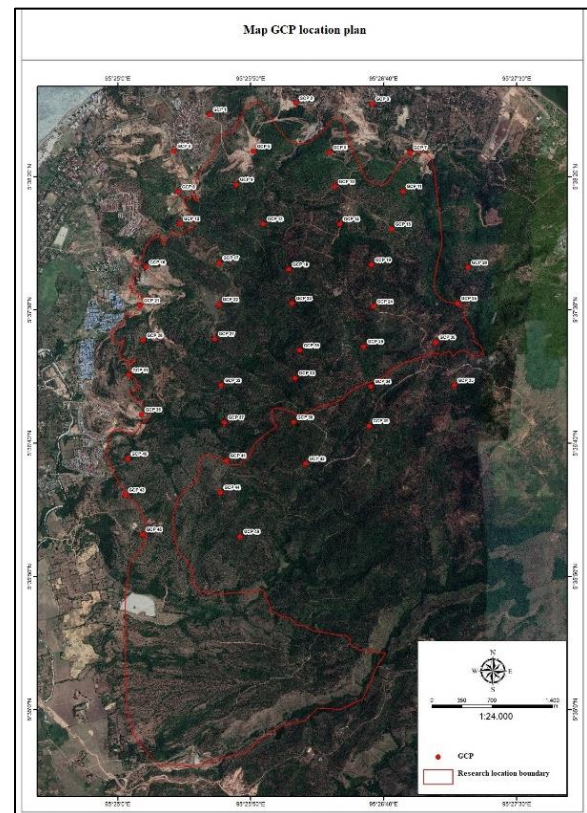


Figure 2. GCP location plan in 8 villages of Darussalam, Baitussalam, and Masjid Raya sub-districts

The Hi-Target V60 geodetic GNSS receiver is the ground control measurement tool. Measurements used the static positioning method, which is the determination of the position of the points that are static. Measurements were made for 60 minutes at each rover point, with a CORS station acting as a base. CORS is an active geodetic frame net in the form of a permanent station equipped with receivers that can receive signals from other GNSS satellites, operating continuously for twenty-four hours. The processing of the CORS binding to the receiver is done by post-processing. In GNSS data processing, the length of the baseline is one of the factors that affect the resulting accuracy. Therefore, in determining the base, the distance between the CORS station that acts as the base and the point to be measured must be considered. In this research, the BIG CORS stations of Sabang City (CSAB) and BIG CORS of Jantho City (CBDA) were used.

UAV Data Capture

Before starting the flight, plan a flight path by determining the area to be mapped shown in Figure 3. Things that need to be done in flight path planning are:

- Determine the area to be mapped, then use a drone deployed on a smartphone for autopilot data acquisition.

- Aerial photo acquisition is carried out in areas with a side overlap of 80% and forward overlap of 80% to facilitate the processing of aerial photos. In the processing of aerial photos. Then the flight path is entered into the drone deploy software for autopilot data acquisition. The DJI Phantom 4 Pro drone is an aerial photography tool. Each flight plan created has an area of 65 hectares and requires two drone flights in each flight path.

GNSS Geodetic Data Processing

Static data processing uses the BIG website <http://inacors.big.go.id/> by entering the RINEX data of static measurement results from geodetic GNSS. The processing results are the coordinate values of latitude, longitude, elevation/surface height, and the accuracy value of the measurement data. The altitude value obtained from this process is an ellipsoid altitude, so it must first be converted into an orthometric altitude through the website <https://srgi.big.go.id>. The latitude, longitude, and altitude coordinate values are then saved in CSV or TXT format to be used as input material at the GCP input stage of aerial photo processing with Agisoft Metashape. The research flowchart is shown in Figure 4 below.

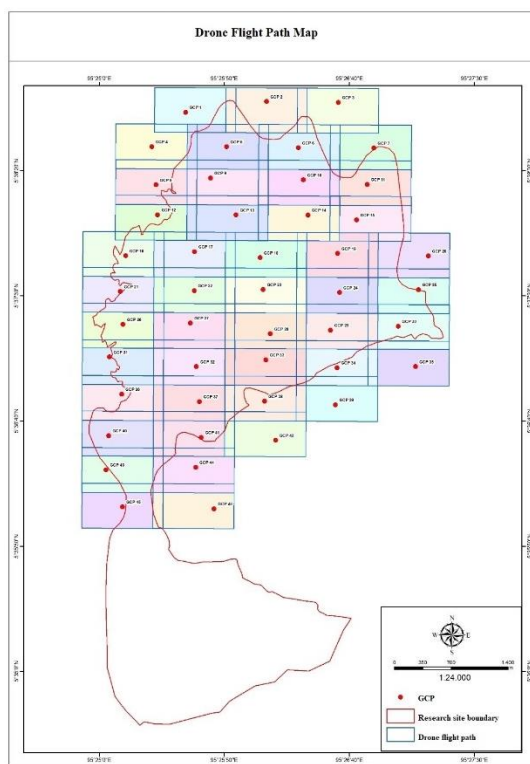


Figure 3. Drone flight path plan in 8 villages of Darussalam, Baitussalam, and Masjid Raya sub-districts

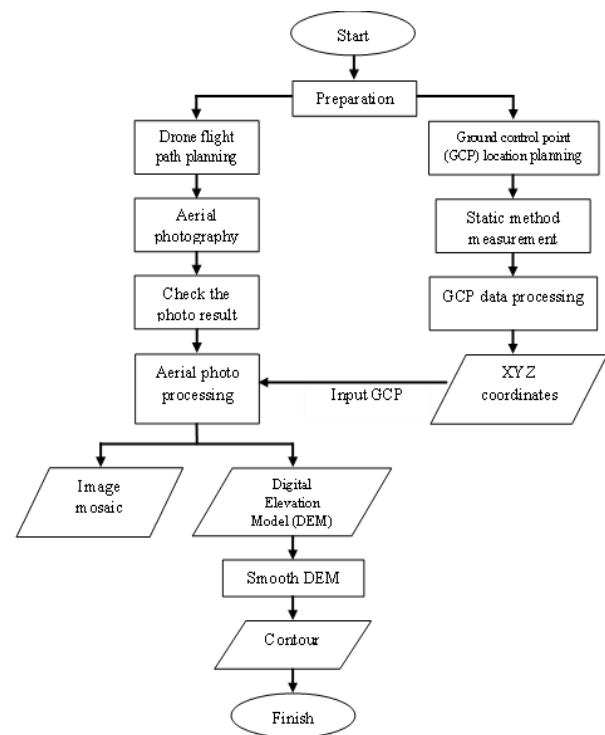


Figure 4. Research flow chart

UAV data processing

Before the processing stage, the aerial photos were checked to avoid blurred photos. Processing the aerial photography data using Agisoft Metashape software.

The steps taken to obtain the mosaic image and DEM are as follows:

- Import photos, the earliest stage to automatically combine survey photos into a whole form.
- Photo Align the stage of checking the points on each photo, then the matching process at the same point contained in two or more photos.
- GCP input from the measurement results is carried out to provide a 3D coordinate reference (XYZ) to the results of the align photo operation so that the formed model can be improved in geometric quality and

ultimately produce accurate DEMs and orthomosaics. At this stage, the default coordinate value of the aerial photo is disabled so that only the coordinates generated from the GCP measurement are used for the next process.

- Build dense point clouds, a collection of thousands to millions of high points, obtained from photogrammetric processing of aerial photographs. The results of this dense point cloud become input material in the construction of DSM or DTM, orthophoto creation, and other purposes.
- Build 3D mesh. This 3D model is the basis for making DEMs, both DSM and DTM, and orthophotos.
- Build DEM (Digital Elevation Model), used to depict a three-dimensional (3D) relief model of the earth to resemble the actual situation.
- Orthophoto is a collection of aerial photographs corrected for geometric errors using DEM and GCP data for mapping purposes without scale inconsistencies along the photo coverage.
- Export orthophoto and DEM is the final stage in processing with Agisoft. Orthophoto and DEM are exported into TIFF format (Marjuki, et al., 2019).

After this stage is completed, the final stage to obtain topographic conditions is to process the DEM data with the ArcMap application to produce contours of the research area.

Filter DEM and generated contour

The DEM generated from Agisoft is a DSM (Digital Surface Model), which still presents the height of objects above the surface. First, it must be filtered using GIS and Remote Sensing applications to remove noise from vegetation, buildings, and others. So that a DTM (Digital Terrain Model) is produced, which is a DEM that only presents the height of the ground surface. This research's final processing stage is to extract contours from the DTM data generated from GIS and Remote sensing such as ArcGIS. Contour extracting is also done using ArcMap software. The contour interval or upright distance between two adjacent contour lines is 1 meter.

Results

Ground Control Point (GCP)

Ground control point or GCP evenly distributed in the study area is measured using static methods. Hence, the raw data results require further processing to obtain coordinate values at the GCP location. Processing uses a website provided by BIG for static data processing with a correction station or base using the CORS station managed by BIG. The processing results obtained are the coordinate values of longitude, latitude, and elevation, along with the level of accuracy. The data generated from GNSS Geodetic has a level of accuracy on the order of cm to mm. Details of the GCP coordinate values can be seen in Table 1 below.

Table 1. GCP point processing results.

Point Name	X (DD)	Y (DD)	Z (m)	Quality (cm)
GCP 1	5,645281	95,42608	54,587	0,05
GCP 2	5,646212	95,43401	38,432	0,33
GCP 3	5,646481	95,44335	9,51	0,11
GCP 4	5,640835	95,423	63,051	0,21
GCP 5	5,641528	95,43029	134,79	0,15
GCP 6	5,641895	95,44016	94,559	0,70
GCP 7	5,642268	95,44834	24,766	0,09
GCP 8	5,636874	95,42303	62,334	0,40
GCP 9	5,638084	95,42901	172,052	5,01
GCP 10	5,63729	95,44009	185,723	0,57
GCP 11	5,636904	95,44481	160,798	0,81
GCP 13	5,633782	95,42898	173,878	0,08
GCP 14	5,633573	95,44081	180,413	1,21
GCP 15	5,633305	95,44552	167,8	3,12

GCP 18	5,629193	95,43453	259,766	1,31
GCP 19	5,630646	95,44323	245,943	0,41
GCP 20	5,629211	95,448	209,424	1,03
GCP 22	5,625389	95,4275	144,12	1,41
GCP 23	5,626161	95,43446	265,061	0,52
GCP 24	5,625719	95,44308	313,595	9,36
GCP 25	5,624626	95,44868	326,438	0,78
GCP 27	5,622195	95,42833	155,596	0,15
GCP 28	5,620917	95,43793	239,062	0,30
GCP 29	5,620608	95,44136	244,917	0,10
GCP 30	5,621199	95,44904	334,841	1,19
GCP 32	5,617227	95,42505	116,559	0,96
GCP 33	5,616887	95,43803	285,589	0,70
GCP 34	5,618017	95,43988	289,269	0,86

Aerial photography

The results of drone recording are aerial photographs of 46 predetermined flight paths. Each flight path produces ± 250 aerial photographs. The aerial photos from drone recordings already have built-in coordinates, but the error rate is still around 2-7 meters. After the GCP input process, the error rate of the aerial photos decreased to below 1 meter. Processing of aerial photographs produces a mosaic image of the research location, DEM, and contours obtained from further processing of DEM data. The DEM and mosaic produced from this processing have a spatial resolution of 5 cm/pixel. The mosaic image results of aerial data recording show the current condition of 8 villages in 3 sub-districts, namely Gampong Cot, Gampong Blang, Krueng Kalee, and Angan in Darussalam Sub-district, Gampong Durung and Neuheun in Masjid Raya Sub-district, Gampong Labuy and Lam Ujong in Baitussalam Sub-district. Mosaic results from satellite imagery shows that most of the area is green, which is a forest area. Some areas in the west and north, such as in block 2 (Gampong Neuhen) are C-excavation mining areas.

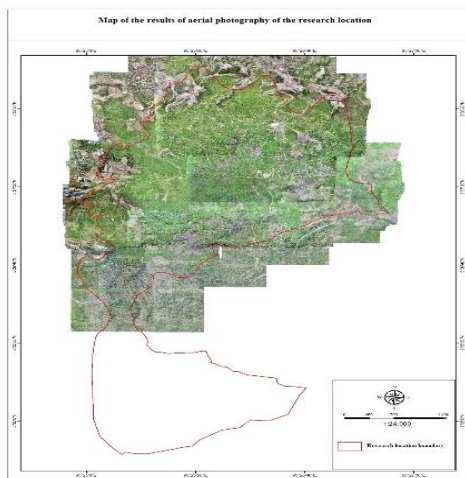


Figure 5. Orthophoto results of the entire research area.

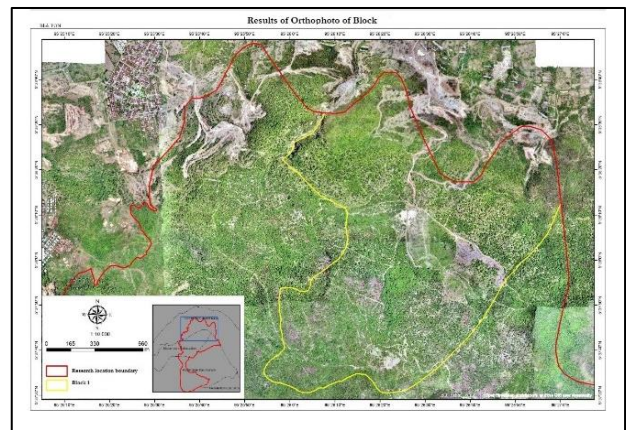


Figure 6. Results of orthophoto of block Gampong Durung, Gampong Cot, Gampong Angan, and Gampong Lam Ujong).

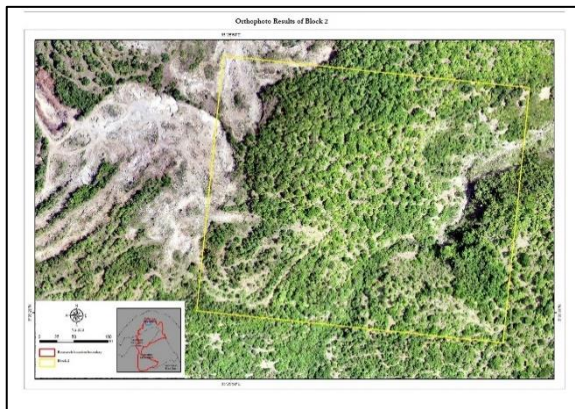


Figure 7. Orthophoto results of block 2 (Gampong Neuhen)

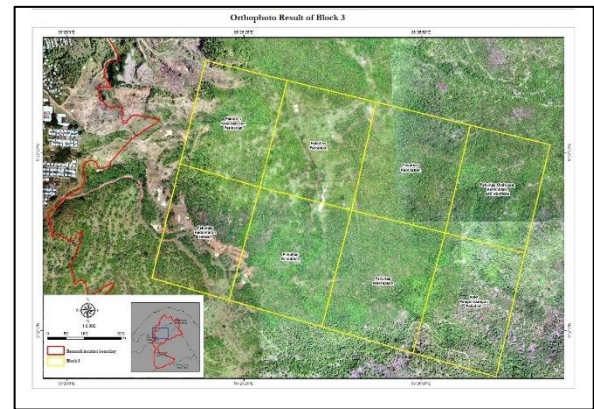


Figure 8. Orthophoto result of block 3 (Gampong Lam Ujong and Labuy)

DEM

The following is a comparison of the initial DEM generated from Agisoft (DSM) with the DEM that has been filtered with ArcGIS (DTM).

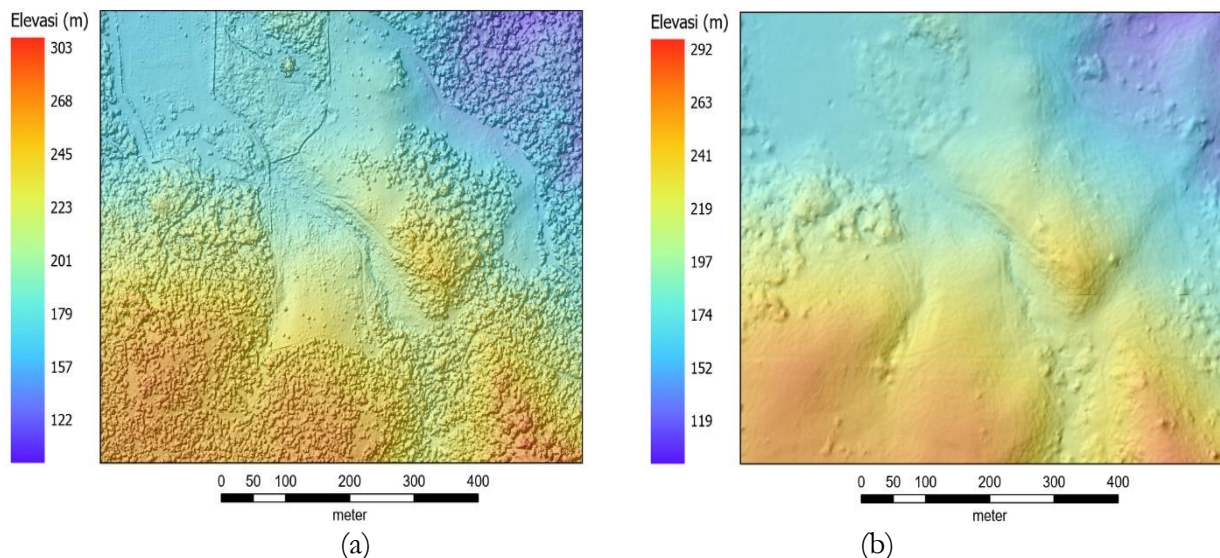


Figure 9. Comparison of DSM (a) and DTM (b)

Figure 9 shows a portion of DSM and DTM from the same region. The difference between DSM and DTM can be seen in the figure. The DSM (the left image) shows a rough surface because the surface still contains a lot of trees on the terrain. The DTM (the right image) shows a smooth surface after filtering all the trees. The DSM also has higher elevation values compared to the DTM because the DSM still includes tree height.

Contour

From the resulting contours, it can be seen that the variation in surface elevation at the study site is quite significant. For block 1, the surface elevation ranges from 66 - 301 meters. The ground elevation is relatively high in the south, a hill area, and decreases in the north. Block 2 has a ground elevation in the range of 90 to 188 m, and block 3 is at an elevation of 50 to 260 meters. The following are the results of contour extraction in the 3 blocks of the research location.

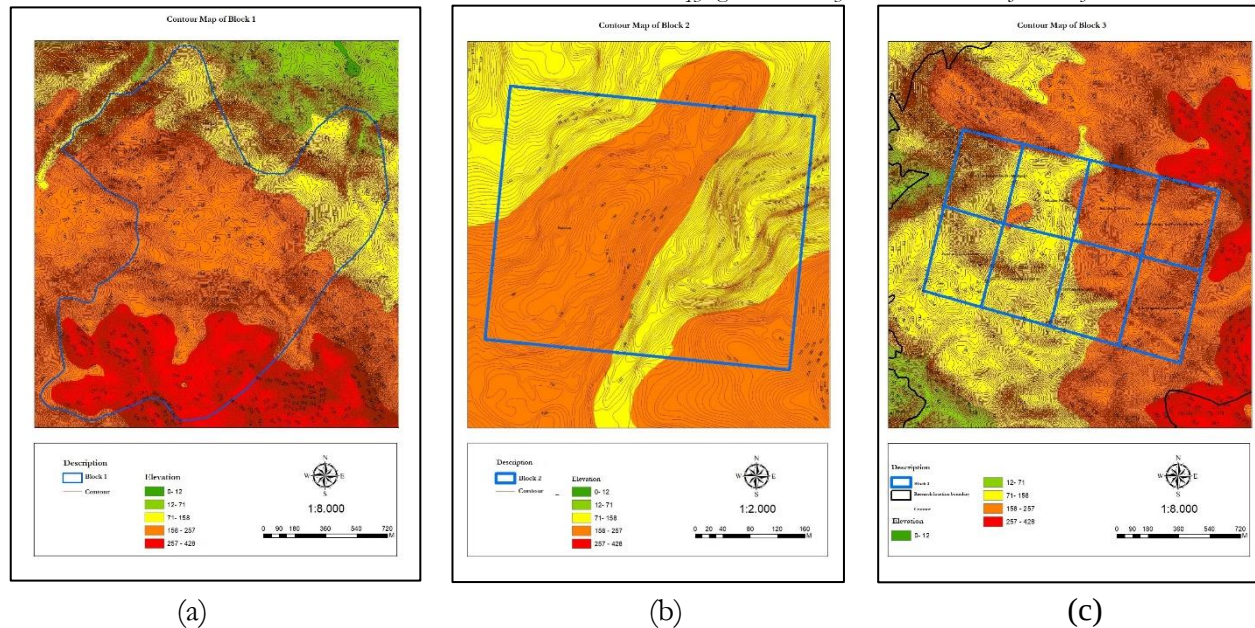


Figure 10. Contours of Block 1: Gampong Durung, Gampong Cot, Gampong Angan, and Gampong Lam Ujong(a), Block 2: Gampong Neuhen (b), and Block 3: Gampong Lam Ujong and Labuy (c)

Discussion

The process of making images and contours from aerial photography results requires ground control points (GCP) to correct geometric errors in aerial photography results. GCP input stages in aerial photo processing greatly affect the results of image accuracy. Research by Meiarti *et al.*(2019) shows a strong relationship between increasing the number of GCPs and decreasing the level of data error vertically and horizontally. In addition, the distribution of GCP points and camera orientation can also affect geometric accuracy. In this study, aerial photos that previously had an error rate of 2-7 meters, after being bound with GCP points, the error rate decreased to below 1 meter. Contouring using UAV cameras is still not widely utilized compared to using LIDAR and Terrestrial Laser Scanning (Ouédraogo, *et al.*, 2014). Rock, *et al.* (2011) compared the results of DEM measurements using LIDAR, photogrammetric techniques, and Geodetic GPS. The study concluded that the photogrammetric drone technique would provide results equivalent to LIDAR if the drone did not fly too high. The higher the drone flies, the lower the results will be. However, in processing DEM data from UAV cameras to produce contours, a filter is needed to remove noise in vegetation, buildings, and others (Figure 9). This process uses DEM Editing in the ArcGIS Software application to produce the land surface contours.

Conclusion

Mapping using UAV technology in this research produces high-resolution image data, which is 5 cm/pixel. Ground Control Point (GCP) is used as a tie point to improve the accuracy of aerial imagery. GCP measurements use geodetic GNSS, which has an accuracy of cm to mm. Aerial photos that previously had an error rate of 2-7 meters, after being bound with GCP points, the error rate decreased to below 1 meter. The aerial photographs show that the land cover in the study area is partly forest. Some areas in the west and north are C excavation mining areas. Based on the contour extract results, the ground elevation of Block 1 is 66 to 301 meters, block 2 is 50 to 260 meters, and Block 3 is 90 to 188 meters.

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