# Application of Unmanned Aerial Vehicle to test Village Map Accuracy, Case Study: Kelurahan Duri Timur

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Abstract: Village mapping was carried out as an implementation of Law Number 4 of 2011 concerning Geospatial Information and Law Number 6 of 2014 concerning Villages. It is defined that the village is a legal community unit that has territorial boundaries that are authorized to regulate and manage government affairs, the interests of the local community based on community initiatives, origin rights, or traditional rights that are recognized and respected in the government system of the Unitary State of the Republic of Indonesia. The management of village potential which includes natural, social, and economic aspects is very important for village development. Therefore, using UAV and GIS applications here is intended as a tool to carry out the process of creating, planning, and validating map data. Mapping using UAV and GIS applications is classified as a photogrammetric measurement where this measurement utilizes aerial photography for data collection. This study aims to produce maps that are accurate and have high accuracy (orthometric) that can be used as a reference in the development process. Information on development planning, spatial planning, investment planning, and economic business, is very helpful for village development. then village mapping using UAV is very appropriate to do. The purpose of this research is to test the geometric accuracy of the UAV technology which in the future the data will be used as input for village mapping. Geometric accuracy (horizontal and vertical) was tested by comparing the ortho mosaic coordinates and the Digital Terrain Model (DTM) to the GNSS RTK measurements. The spatial data generated from UAV technology in this study has a geometric accuracy of 1.9018 m horizontally and 2.253 m vertically so that it can still be used for large-scale mapping of 1:5000.

## 1 INTRODUCTION

Law on Villages Number 6 of 2014 mandates that Villages have a village information system containing village data, village development data, rural areas, and other village and regional development information. In article 86 of Law no. 6 of 2014, The Village Information System will be complete and informative if it has Geospatial Information that contains various things the village needs and is presented visually on a map. Geospatial information (maps) as a survey and mapping product is easy to produce, disseminate, and use together by all parties for planning, implementation.

East Duri Village is one of the villages which is administratively located in Mandau District, Bengkalis Regency. Based on the Central Bureau of Statistics, Bengkalis Regency, Duri Timur Village has around 1.70 km2 or 170 hectares with 14,440 people.

Unmanned Aerial Vehicle (UAV) or drone is a new technology for mapping, especially aerial photo shooting. Mapping with UAV has advantages when compared to mapping using terrestrial measurements. The advantages of using a UAV for mapping include visualization of data in aerial photos integrated with GPS coordinate data; in terms of time, it is more efficient and economical where the UAV can do large-scale mapping quickly. More and more foreign and domestic researchers and practitioners are using and developing UAVs for various mapping applications. UAV is an alternative to cheap remote sensing technology as a source of spatial data (Bendea. H et al., 2008; Adam, S.M et al., 2011; Rokhmana, 2012).

Accurate village maps are important spatial data for decision-makers in village government. In addition, accurate spatial data can guide village development planning, such as determining village administrative boundaries, boundaries for RT/RW villages, a reference in determining village boundaries for expansion, and a complete village profile.

This research was conducted by Rini Meiarti et al. (2019). This study tested the accuracy of the results of UAV technology mapping in coastal disaster applications. The method used for the accuracy test is the geometric accuracy-test both horizontally and vertically. At the same time, the semantic quality test of aerial photographs is assumed to have the smallest object interpretability that can be found in the orthophoto mosaic. Naryoko et al. (2019) conducted a study on the application of UAV technology in


making village maps at a scale of 1:1000. The method used to test the accuracy of the map is based on PERKA BIG No. 15 of 2014 concerning technical guidelines for the accuracy of the base map.

UAV application for village mapping produces orthophoto mosaic data, elevation data in the form of Digital Elevation Model (DEM) data, and Denscloud data for 3D data. This data needs to be tested for accuracy based on PERKA BIG No. 15 of 2014, namely the geometric accuracy test. Many factors strongly influence the geometric accuracy of aerial photos acquired with UAV technology. Factors include vehicle type, sensor type, flight altitude, acquisition time, weather conditions, processing software, and human resource/operator capabilities. Proving that accuracy will affect the level of confidence in the resulting map. Maps with high accuracy or precision can increase the power of information for policy makers' decision-making (Rini Meiarti et al., 2019).

# 2 METHOD

This research method begins with planning the flight path of aerial photography with UAV, namely how to plan aerial photography for mapping purposes. After there is a map of the planned flight path, the next step is to determine the ground control point of the plan, which will then be installed with a tarp as a binding point for aerial photography. After all the initial preparations are completed, then aerial photography is carried out in the study area. The aerial photos will be processed into orthophoto data and Digital Elevation Model (DEM) for mapping. The geometric accuracy test of aerial photo data is carried out by comparing aerial photographs using UAV with data from the measurement results of point samples in the field using Geodetic GPS called Ground Control Points (GCPs) and Independent Control Points (ICPs

## 2.1 Material and Methods

### 2.1.1 Study Site

East Duri Village is one of the villages which is administratively located in Mandau District, Bengkalis Regency. Based on the Central Bureau of Statistics, Bengkalis Regency, Duri Timur Village has around 1.70 km2 or 170 hectares with 14,440 people.


Figure 2.1 Site Location.

### 2.1.2 Material and Equipment

1. UAV Fixed Wing with specification :
   - Wingspan 1.8 Meter.
   - Length of body 1.4 Meter.
   - Camera Sony Nex 5,16mm Lens, F/2.8
   - EPO + Carbon Fiber Based
   - Maximum fly height 700 m
   - 6 Kg weight

Figure 2.2 The UAV Fixed Wing

2. GPS Geodetic with accuracy RTK (L1+L2) H:5mm+0.5ppm, V:10mm+0.8ppm.
3. GPS Handheld Garmin
4. Marker Ground Control Points (GCPs) 100 cm x 100 cm, orange color.
5. Software used for data processing :
   - Agisoft Metashape Professional
   - Ardupilot Mission Planner
   - Global Mapper
   - ArcGIS
   - Google Earth Pro

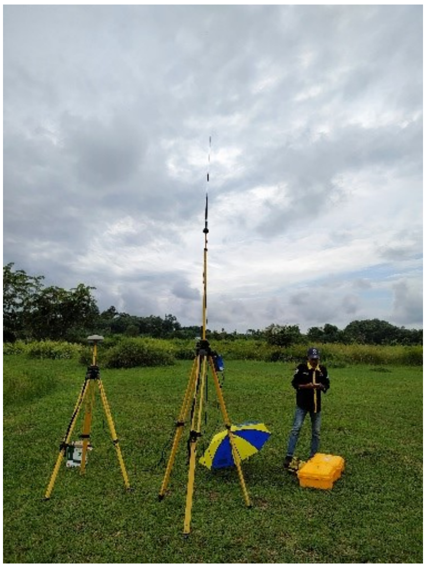

Figure 2.3 GNSS Geodetic Trimble R8s

## 2.2 Implementation Stage

1. Determination of the Area of Interest (AOI) or Boundary of the survey point plan using Google Earth Pro software.
2. Determination of the planned Ground Control Point (GCP) tie point using Google Earth Pro software.
3. Determination of the planned flight path in the Area of Interest (AOI) or Boundary using the Mission Planner software.
4. Selection of take-off and landing areas of the aircraft.
5. Aerial photography of the study area.
6. Measurement of GCP and ICP points in the field using GPS Geodetic.
7. Processing aerial photos from UAV shooting with digital photogrammetry techniques to produce DSM and Orthophoto data using Agisoft Metashape software.
8. Calculation of Orthophoto and DSM geometry accuracy test results from digital photogrammetry processing of aerial photos.

### 2.2.1 Flight Mission Planning

The area of aerial photography in this study is ±170 ha, located in East Duri Village, Mandau District, Bengkalis Regency.

In this study, the output of aerial photography is expected to have great detail and accuracy of geometry both horizontally and vertically. This aerial photo map is planned to meet the geometric accuracy standard of the RBI map with a scale of 1: 5000 issued through the Head of BIG Regulation No. 15 of 2014.

Figure 2.4 Photoshoot area in East Duri Village, Mandau District, Bengkalis Regency.

Flight Mission Planning using the mission planner software. Before acquisition data, the parameters are configured in the software. The configuration is as follows:

- Altitude : 300 Meters
- Frontlap/Sidelap : 80/70
- Speed : 10-15 m/s
- Compass Calibration
- IMU Calibration

Figure 2.5 Plan a Flying Mission by Using the Mission Planner App

### 2.2.2 Planning and Measurement of Ground Control Points (GCPs) and Independent Control Points (ICPs) distributions

The design of the distribution and the number of GCP placements should represent the topographic configuration and relief. GCP is used for the block bundle adjustment process in the photogrammetry software so that the point cloud coordinates, which were initially model, become actual coordinates in the field. In addition, ICP is a field coordinate used to test the Orthophoto and Digital Surface Model (DSM) accuracy resulting from aerial photo processing.

GCP and ICP measurements in the field use geodetic GNSS, with a measurement accuracy of each point capable of reaching centimeters or below the pixel size of aerial photographs. The number of GCPs used for processing is at least 3 points, while for ICP, it is better to exceed the number of GCPs.

Figure 2.6 GCPs Coordinate Measurement

Ideally, in aerial photography, remark placement and GCP measurements are carried out before shooting, but in this study, postmarking, GCP, and ICP measurements were carried out after aerial photography. The object's appearance selected as GCP and ICP should be clear and contrasting, not moving, and the object being fixed or not changing or shifting much for a long time. Examples of suitable objects for GCP and ICP points are corners of crossroads, buildings (not roofs), road markings, intersections of rice fields, and other similar objects.

This study places GCP at 6 points and ICP at 3 points

Figure 2.7 Distribution of GCP and ICP Locations in Research Sites

### 2.2.3 Aerial Photo Data Acquisition

From the results of aerial photography that has been carried out, the results obtained are 932 aerial photos with a flying height of 300 meters. The area photographed is ±170 Ha.

### 2.2.4 GCP and ICP Data Acquisition

Ground Control Points (GCPs) and Independent Control Points (ICPs) data were obtained in the field using GPS Geodetic in the form of UTM coordinate data, which will later be used to test map accuracy in this study.

Table 2.1 GCP and ICP Data Acquisition Results

| Titik | X | Y | Z |
|---|---|---|---|
| GCP 1 | 240874.234 | 9949133.567 | 7.547 |
| GCP 2 | 240515.544 | 9948790.617 | 7.355 |
| GCP 3 | 241171.816 | 9948742.867 | 7.34 |
| GCP 4 | 240125.477 | 9949205.03 | 7.565 |
| GCP 5 | 242169.702 | 9948827.608 | 7.835 |
| GCP 6 | 241752.315 | 9949530.667 | 7.494 |
| ICP 1 | 241317.686 | 9949308.918 | 8.655 |
| ICP 2 | 241043.511 | 9949685.506 | 8.808 |
| ICP 3 | 241215.348 | 9949472.702 | 8.866 |

### 2.2.5 Aerial Photo Processing To Orthomosaic and DSM

Processing of aerial photos from UAV data into Orthomosaic and DSM using digital photogrammetry, the software used is Agisoft Metashape. This software processes aerial photo data taken by UAV into Orthomosaic digital data and DSM (Digital Surface Model).

This processing requires an input of the field's x, y, and z coordinates, which are captured with Geodetic GPS. The coordinates as input to the process are called Ground Control Points (GCPs) to correct the model coordinates from the point cloud to actual coordinates in the field.

# 3. RESULT

## 3.1 Map Formation Results and Analysis

Results and analysis of orthophoto formation The following are the results of orthophoto formation from the UAV aerial photo processing process, which can be seen in Figure 2.4. Nine hundred thirty-two photos with an area of ± 170 ha and a flying height of 300 m formed Orthophoto, and the Agisoft Metashape software processes this data.

Figure 3.1 Orthophoto Forming Result

## 3.2 Building DEM

From the DEM results obtained, it is known that the minimum and maximum heights of Duri Timur Village, Mandau District, Bengkalis Regency are 2 meters and 20 meters.

The DEM resolution obtained is 2.07m/pix with an interpolation point density of 0.233 points/m², and it can be seen that there is a reasonably sharp difference in height. DEM is an interpolation process from several point clouds that have been extracted from aerial photos, while Orthophoto is the result of merging from aerial photos from acquisitions, so DEM resolution has a difference from orthophoto resolution.

The following are the results of the DEM formed from the UAV aerial photo processing process carried out, which can be seen in figure 2.5.

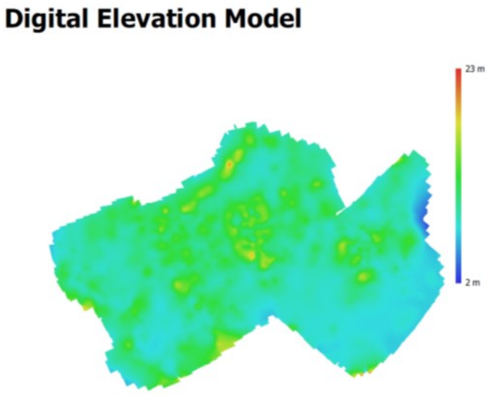


Figure 3.2 DEM Forming Results

## 3.3 Ground Sampling Distance (GSD) Test

GSD or Ground Sampling Distance measures the pixel resolution of aerial photos, both aerial photos with metric cameras and aerial photos with non-metric cameras. The GSD value is often used as a benchmark for the quality of the resulting aerial photos. By setting the GSD value, the user requires flying height and camera-resolution with apparent parameters. Determine the value of this GSD using the following formula:

$$\text{GSD} = \frac{\textit{Flight Height}}{\textit{Focal Length}}\ x\ \textit{Pixel Size}$$

The following is a valid table of aerial shooting results in the field using a Fixed Wing UAV processed with Agisoft Metashape:

Table 3.1 Report Camera from Software Agisoft

| Camera Model | Resolution | Focal Length | Pixel Size | Precalibrated |
|---|---|---|---|---|
| ILCE-6000 (20mm) | 6000 x 4000 | 20 mm | 4 x 4 μm | Yes |

With a flying height of 300 meters, a focal length of 20 mm, and a pixel size of 4 x 4 m, the GSD is obtained:

$$\text{GSD} = \frac{300\ \text{m}}{0{,}02\ \text{m}}\ \text{x}\ 0.000004\ \text{m} = 0{,}06\ \text{m/pix}$$

## 3.4 Geometry Accuracy Test (Horizontal and Vertical)

The method used to test the accuracy of the data is based on PERKA BIG no. 15 of 2014 concerning Technical Guidelines for Base Map Accuracy. The geometric accuracy test was applied to the orthophoto mosaic to determine the accuracy and horizontal position error, while the vertical accuracy or altitude error was tested on the Digital Terrain Model (DTM).

The horizontal position accuracy-test refers to the difference in coordinates (X, Y) between the test point on the map and the actual test point on the ground. Accuracy measurement uses Root Mean Square Error (RMSE). RMSE is used to describe accuracy, including random and systematic errors; this RMSE can be calculated when the coordinate transformation is complete.

The vertical position accuracy-test refers to the difference in coordinates (Z) between the test point on the map and the actual test point on the ground. The accuracy measurement uses the Root Mean Square Error (RMSE). RMSE is used to describe accuracy, including random and systematic errors; this RMSE can be calculated when the coordinate transformation is complete.

Then the horizontal and vertical RMSE parameters are multiplied by the Circular Error 90 (CE90) and Linear Error 90 (LE90) parameters to determine the geometric accuracy standard of the RBI map.

CE90 and LE90 values can be calculated based on the formula:

$$CE90 = 1{,}5175 \times RMSExy \qquad (2.1)$$

$$LE90 = 1{,}6499 \times RMSEz \qquad (2.2)$$

Table 3.2 Provisions for RBI Map Accuracy Value Based on Class

| No | Accuracy | Class 1 | Class 2 | Class 3 |
|---|---|---|---|---|
| 1 | Horizontal | 0.2 mm x Scale | 0.3 mm x Scale | 0.5 mm x Scale |
| 2 | Vertical | 0.5 x Contour Interval | 1.5 x Contour Interval | 2.5 x Contour Interval |

Table 3.3 Horizontal Accuracy Test Results

| Point Name | Dx | $Dx^2$ | Dy | $Dy^2$ | $Dx^2 + Dy^2$ |
|---|---|---|---|---|---|
| ICP 1 | -0.818 | 0.669 | 0.356 | 0.127 | 0.796 |
| ICP 2 | -1.135 | 1.288 | 0.207 | 0.043 | 1.331 |
| ICP 3 | 1.528 | 2.335 | 0.500 | 0.25 | 2.585 |
| | | | Total | | 4.712 |
| | | | Average | | 1.571 |
| | | | RMSEr | | 1.2532 |
| | | | CE90 | | 1.9018 |

Table 3.4 Vertical Accuracy Test Results

| Point Name | Dz | $Dz^2$ |
|---|---|---|
| ICP 1 | -1.595 | 2.544 |
| ICP 2 | -1.311 | 1.719 |
| ICP 3 | -1.154 | 1.332 |
| | Total | 5.594 |
| | Average | 1.865 |
| | RMSEz | 1.365 |
| | LE90 | 2.253 |

### 3.5 Map Accuracy Test Analysis

The horizontal accuracy test is indicated by the CE90 value and vertically by the LE90 value. These two values will be compared with the standard value of the base map referring to the Regulation of BIG No. 15 of 2014, as shown in table 2.3.

Table 3.5 CE90 Calculation Results

| RMSEr | CE90 (m) | Scale | Class |
|---|---|---|---|
| 1.2532 | 1.9018 | 1:5000 | Class 3 |

Table 3.6 LE90 Calculation Results

| RMSEz | LE90 (m) | Scale | Class |
|---|---|---|---|
| 1.365 | 2.253 | 1:5000 | Class 3 |

The calculation results in tables 2.6 and 2.7 show that CE90 and LE90 are smaller than the standard value of 2.5 (obtained from the calculation of table 2.3). Furthermore, the values show that the orthophoto results formed have good accuracy both horizontally and vertically.

## 4 CONCLUSIONS AND SUGGESTIONS

### 4.1 Conclusion

Aerial photos taken using a Fixed-wing UAV with a horizontal geometric accuracy of CE90 1.9018 and a vertical geometric accuracy of LE90 2253 are suitable for mapping a scale of 1:5000 and falling into class 3 of the DSM and DTM data.

Geometric accuracy tests from aerial photos produced by UAV technology can still be developed to compare the vehicle's side, sensors, processing software, shooting techniques related to altitude differences, and compare objects in different area characteristics, including the area mapped.

### 4.2 Suggestion

Based on the research that has been done from beginning to end, the following suggestions can be put forward for further research:

1. The flying height of the UAV should be lower to get more precise and accurate aerial photos.

2. In shooting with UAVs, the UAV's flight height is kept as low as possible while considering the height of the obstacle so that the resolution can be maximized. Sidelap and Frontlap values are made high to avoid data holes due to lack of overlap.

3. Positioning of GCP points to consider obstruction conditions for GPS observations. Avoid placing GCP points in places where there is electrical interference and multipath interference.

4. To get maximum results, data processing with Agisoft is done by using the high option so that there is no decrease in data quality from the report results.

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