ULITIZING POST PROCESSING KINEMATIC (PPK) UNMANNED AERIAL VEHICLE (UAV) TO ACCELERATE DETAILED LAND MAPPING

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Abstrak. The accelerate of land registration is important to solve the land disputes. Start from 2022, BPN utilize UAV to make base maps quickly. One of photo map criteria is high horizontal accuracy of <0.5 meter by using Circular Error 90% (CE90). This research analyzes the effectiveness of PPK method on UAV survey to accelerate detailed land mapping in Indonesia. UAV fixed wing Vertical Takeoff and Landing (VTOL) model with Sony ILCE-6000 camera flown on 9.46 km^2 areas, flying on 244 meters, and using 8 Ground Control Points (GCP) in Muktisari Village, Ciamis. First, UAV camera coordinates processed to obtain photo mosaic. Furthermore, geometric correction processed with GCP to obtain orthophoto for each mosaic photo. The UAV without PPK produced CE90: 0.02 meter (RMSE: 0.013 meter), whereas the UAV using PPK produced CE90: 0.008 meter (RMSE: 0.005 meter). According to the CE90 value on UAV showed resulting photo map included in 1:1000 scale aerial photo map in class 1. However, this research showed the UAV using PPK is 2.5 times more accurate. In conclusion, PPK can improve the performance of UAV to increase the photo map geometry accuracy. Hence, UAV using PPK are recommended to accelerate detailed land mapping in Indonesia.
Keyword: UAV; PPK; GCP; Detailed Land Mapping

INTRODUCTION

Agrarian or land issues are the most reported in Indonesia. In 2022, 339 reports cited agrarian substances (Ombudsman, 2022). To resolve land issues or disputes, the government implemented a Complete Systematic Land Registration (PTSL). Beginning in 2022, BPN use UAV technology to accelerate the mapping process, particularly when creating base maps. In the form of photo maps, image maps, and line maps from terrestrial mapping, the basic land map contains thematic geospatial information that serves as the foundation for land registration activities in Indonesia. For the procurement of photo maps, there are several output criteria, such as GSD 0.15 m, CE90 1.5 m, and image visualization is clear, not blurry, not broken, and not curved.

GCP is commonly used for geometric correction on UAVs. GCP is measured by observing using Global Navigation Satellite System (GNSS) tools spread across the work site. GCPs must be installed as part of a network, which takes time. The quantity and distribution of GCPs then have an impact on accuracy (Sanz-Ablanedo et al., 2018). Furthermore, the disadvantage of GCPs is depending on the soil conditions and observation sites, GCPs cannot be placed in difficult terrain for practical or safety reasons (Zhang et al., 2019). PPK-GNSS is thus used to maximize performance in geometric correction, stabilization, and GCP measurements to save time and resources (Dinkov & Kitev, 2020). The PPK GNSS has been used in numerous studies for UAV surveys (Sanz-Ablanedo et al., 2018; Tomaštík et al., 2019; Taddia et al., 2020; Elkhrachy, 2021). However, geometric correction using the PPK method still requires less GCP than geometric correction without PPK.

Thus, the purpose of this study was to assess the effectiveness of the PPK method for geometric correction in UAV surveys to accelerate detailed land mapping in Indonesia using the parameter conditions established by the Indonesian National

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Land Agency. This study on geometric accuracy is limited to CE90 measurements.

METHOD

This part explains the geometric accuracy of land base map. The coordinates of the UAV obtained from the original imagery, point clouds, and orthophoto were compared to the coordinates in the outputs in the following manner.

The root mean square coordinate errors are calculated as follows:

$$RMSE_x = \sqrt{\frac{\sum_{i=1}^{n} \Delta x_i^{\,2}}{n}} \qquad (1)$$

$$RMSE_y = \sqrt{\frac{\sum_{i=1}^{n} \Delta y_i^{\,2}}{n}} \qquad (2)$$

$$RMSE_z = \sqrt{\frac{\sum_{i=1}^{n} \Delta z_i^{\,2}}{n}} \qquad (3)$$

where x_i, y_i, and z_i are the differences between the reference coordinates and the determined UAV coordinates. The number n denotes the number of points in the set. To enable a more detailed analysis of the Remote Sensing of vertical accuracies, the minima, maxima, means, and standard deviations for z_i were calculated. The root mean square horizontal error $RMSE_{xy}$ was calculated using the $RMSE_x$ and $RMSE_y$ errors as follows:

$$RMSE_{xy} = \sqrt{RMSE_x^{\,2} + RMSE_y^{\,2}} \qquad (4)$$

The $RMSE_{xy}$ is a common horizontal accuracy criterion for sets of points and was used as the primary measure to compare data from different datasets.

According to Regulation of the Minister of Agrarian Affairs and Spatial Planning/Head of the National Land Agency (BPN) No. 21 of 2019, the smallest scale for making base maps with aerial photographs is 1:5,000, with a maximum class 1 horizontal accuracy of 1.5 m (Table 1). Horizontal accuracy is defined here as Circular Error 90% (CE90), which is a measure of horizontal geometric accuracy defined as the radius of a circle indicating that 90% error or the difference in the horizontal position of objects on the map with the actual position being no greater than that radius (BIG, 2014). The CE90 equation is shown below.

$$CE90 = 1{,}5175 \times RMSE_r \qquad (5)$$

$$RMSE_r = \sqrt{\frac{(x_{data} - x_{cek})^2 + (y_{data} - y_{cek})^2}{n}} \qquad (6)$$

RMSEr = Root Mean Square Error at the x and y positions (horizontal).

Tabel 1. The Geometric Accuracy of Land Base Map (BPN, 2019).

No	Scale	Contour Interval	Class 1 Horizontal Accuracy	Class 2 Horizontal Accuracy	Class 3 Horizontal Accuracy
1	1:10.000	4	3	6	9
2	1:5.000	2	1.5	3	4.5
3	1:2.500	1	0.75	1.5	2.3
4	1:1.000	0.4	0.3	0.6	0.9

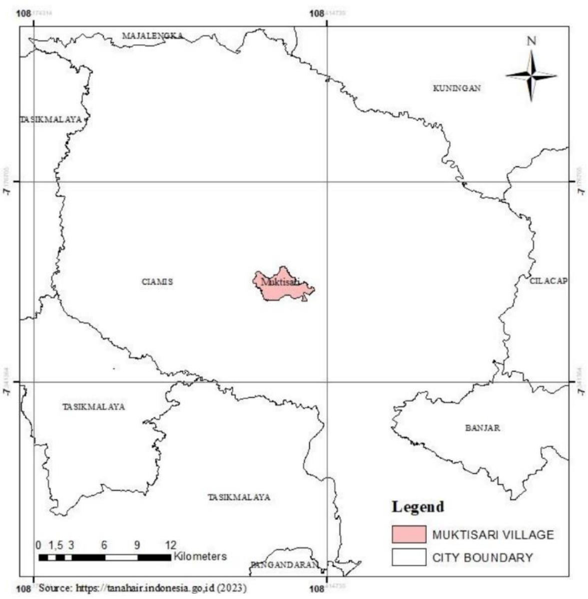

Figure 1. Research Location

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STUDY SITES

The study was carried out in Muktisari Village, Cipaku District, Ciamis Regency. Muktisari Village covers 9.28 square kilometers and is located at an elevation of 250 meters above sea level (BPS, 2021). In Ciamis Regency, Muktisari Village is a obtaining high-quality data in high-elevation areas is more difficult than in low-elevation areas. So, if the results obtained at this location are good, the study assumes that it can be applied to any location, both highlands, and lowlands. Figure 1 depicts the study's location.

MATERIAL

To survey this study, a UAV fixed-wing Vertical Takeoff and Landing (VTOL) model aircraft equipped with a Sony ILCE-6000 camera with a camera resolution of 3008x2000 and GNSS PPK technology was used. The Table 2 provides a more detailed explanation of the UAV VTOL used in this study. Furthermore, Agisoft Metashape Professional data processing software was used in this study. Data processing on a computer with an Intel® Core (YM) i9 NVIDIA GeForce RTX 3060.

Figure 2. UAV VTOL

Table 2. UAV VTOL Specification

No	Specification	Description
1	Item Name	UAV VTOL
2	Material	EPO
3	Wingspan	2160 mm
4	Length	1200 mm
5	Wing Area	60 dm
6	Max. Flying Weight	6-8 kg
7	Economic Flight Speed	15-22 m/s
8	Flying Time	120 Minutes
9	Camera Cabin Dimension	150x90x250 mm
10	Camera Cabin Cover Opening Width	130

ACQUISITION DATA AND DATA PROCESSING

On December 14, 2022, a UAV VTOL equipped with GNSS PPK technology was used to survey the study sites. The table 3 shown the GNSS specification that used in this research.

Table 3. GNSS Specification

GNSS Characteristic			
1	Channels	:	432
2	GPS	:	L1, L2, L2C, L5
3	Glonass	:	L1, L2
4	BeiDou	:	B1, B2, B3
5	SBAS	:	L1
6	QZSS	:	L1, L2, L5
GNSS Accuracy			
Real Time Kinematics (RTK)			
1	Horisontal	:	8 mm+ 1 ppm RMS
2	Vertikal	:	15 mm + 1 ppm RMS
3	Innitial Time	:	<10 S initialization reliability : > 99.9 %
Post-processing kinematics (PPK):			
1	Horisontal	:	3 mm + 1 ppm RMS
2	Vertikal	:	5 mm + 1 ppm RMS
Post-processing static:			
1	Horizontal	:	3 mm + 0.5 ppm RMS
2	Vertical	:	5 mm + 0.5 ppm RMS
Code differential:			
1	Horizontal	:	0.4 m RMS
2	Vertical	:	0.8 m RMS
Autonomous:			
1	Horizontal	:	1.5 m RMS
2	Vertical	:	3.0 m RMS
Positioning rate		:	Up to 10 Hz
Ti me to first fix			
1	Cold start	:	< 45 s
2	Hot start	:	< 10 s
3	Signal re-acquisition	:	< 1 s
Hardware			
Size (L x W x H)		:	140 mm x 130 mm x 106 mm(5.5 in × 5.1 in × 4.2 in)
Weight		:	1. 29 kg (2.8 lb)

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Environment :		
Operating	:	-40 °C to +65 °C (-40 °F to +149 °F)
Storage	:	-40 °C to +75 °C (-40 °F to +167 °F)
Humidity	:	95%
Ingress protection	:	IP67 waterproof and dustproof, protected from temporary immersion to depth of 1 m
Shock	:	Survive a 2-meter pole drop
Tilt sensor	:	EBubble leveling
Front panel	:	6 status LED

Data collection over a 9.46 km2 area at a flying height of 244 meters above the ground. The UAV flies at 244 m because of the very towering trees at the research site. Furthermore, GCP measurements were taken using the static method at eight different locations throughout the study site. The coordinate taken by GCP around 30 minutes. The GCP location shown on Figure 3. Following the acquisition of aerial photo data and ground control points. On a computer, data processing was carried out using the agisoft metashape professional software. Geometric data processing was performed using GCP and twice processes in this study, with UAV data processing without PPK and UAV data processing with PPK.

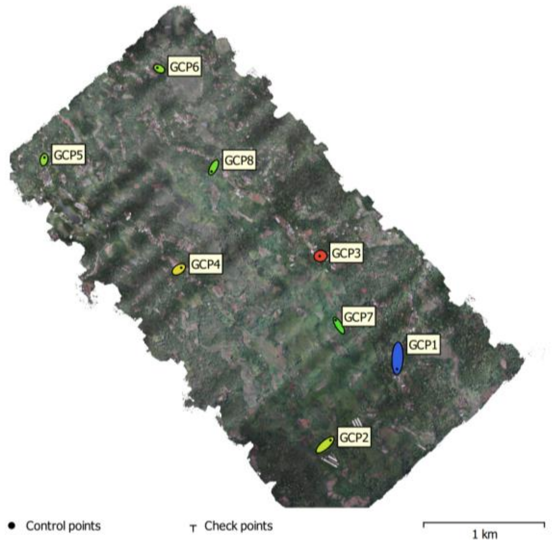

Figure 3. The GCPs Location

First, the process of photo mosaic is aligning the photos to identify the points on the photos to obtain matching points between photos. In high accuracy mode, the alignment process on UAV data without PPK is used. Meanwhile, the UAV data collected with PPK is in medium accuracy mode. Next, create dense clouds and depth filtering to generate orthophotos. UAV data without PPK is processed at this stage using high-quality mode and mild filtering mode. Furthermore, UAV data processed with PPK is processed in medium-quality mode with mild filtering. The WGS 84/UTM zone 49S (EPSG:32749) coordinate system is used in the orthomosaic process, with the size of the UAV without PPK being 56.613x57.423 and the UAV using PPK being 54.580x60.058. The geometric correction process for each photo mosaic is the next step after the photo mosaic is formed. The GCP coordinates obtained from GNSS measurements in the field at up to 8 points spread across the study site were attached to the GCP points on each photo mosaic, resulting in photo coordinates that match the coordinates in the field and the formation of an orthophoto. After the orthophoto process is completed, error results for each coordinate (X, Y, and Z) will be obtained, allowing the accuracy of the survey results to be determined.

RESULT AND ANALYSIS

This study compares the processing of UAV data without GNSS-PPK data to UAV data with GNSS-PPK data to determine the level of effectiveness of GNSS PPK on UAV surveys. Data processing with the Agisoft Metashape Professional software results in an internal photogrammetric process report, as shown in the table 4.

According of table 4, data processing without PPK produces more aligned, tie points, and dense clouds than data processing with PPK. Furthermore, the reprojection error for non-PPK is lower than that for PPK. This is because the parameters assigned to non-PPK processing at Agisoft are high accuracy, whereas PPK is medium accuracy. This demonstrates that the parameters are chosen when processing data in agisoft have an impact on the photo processing results. The examples below show how to calculate without and using PPK. Each method's example in GCP 1.

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a. Calculation example for GCP 1 without PPK

$$RMSE_{xy} = \sqrt{RMSE_x{}^2 + RMSE_y{}^2}$$

$$RMSE_{xy} = \sqrt{-0.001^2 + -0.025^2}$$

$$RMSE_{xy} = 0.025$$

a. Calculation example for GCP 1 with PPK

$$RMSE_{xy} = \sqrt{RMSE_x{}^2 + RMSE_y{}^2}$$

$$RMSE_{xy} = \sqrt{-0.001^2 + -0.009^2}$$

$$RMSE_{xy} = 0.009$$

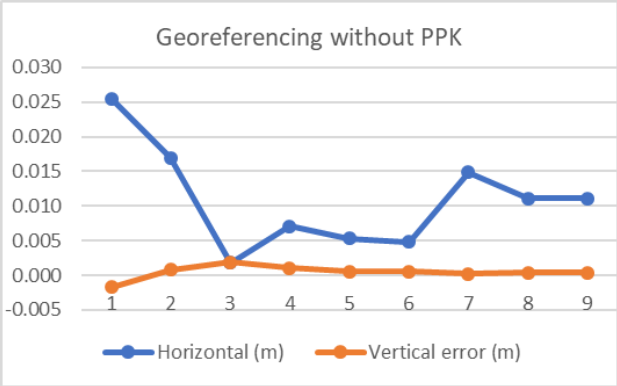

Figure 4. Position of Errors in the validation's points for UAV without PPK

Table 4. Results of photogrammetric processing flight patterns and GCP configurations

		Point Count			
No	Georectification Method	Cameras Total/Aligned	Tie Points	Dense Cloud	Reprojection Error (pixel)
1	8 GCP & No PPK	1851/1851 (100%)	1,561,862	629,918,312	0.365
2	8 GCP & PPK	2020/2053 (98%)	513,571	173,209,345	0.601

Table 5. Errors of checkpoints for UAVs without PPK

Label	X error (m)	Y error (m)	Horizontal Error (m)	Vertical error (m)
GCP1	-0.001	-0.025	0.025	-0.002
GCP2	0.013	0.011	0.017	0.001
GCP3	-0.002	0.000	0.002	0.002
GCP4	0.006	0.004	0.007	0.001
GCP5	0.001	0.005	0.005	0.001
GCP6	-0.004	0.002	0.005	0.001
GCP7	-0.008	0.013	0.015	0.000
GCP8	-0.005	-0.010	0.011	0.000
GCP8	-0.005	-0.010	0.011	0.000
Total	0.006	0.012	0.013	0.001

Table 6. Errors of checkpoints for UAV with PPK

Label	X error (m)	Y error (m)	Horizontal error (m)	Vertical error (m)
GCP1	-0.001	-0.009	0.009	-0.001
GCP2	0.003	0.000	0.003	0.001
GCP3	-0.002	0.001	0.003	0.004
GCP4	0.001	0.000	0.001	0.001
GCP5	0.001	0.001	0.001	0.000
GCP6	-0.001	0.001	0.001	0.000
GCP7	-0.001	0.010	0.010	0.002
GCP8	0.000	0.000	0.000	0.002
GCP8	0.000	0.000	0.000	0.002
Total	0.002	0.005	0.005	0.002

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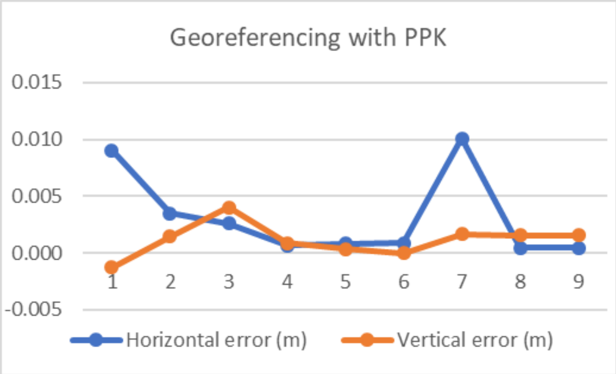

Figure 5. Position of Errors in the validation's points for UAV with PPK

Table 5 shows coordinate errors (X, Y, and Z) from the UAV validation point when the PPK method is not used and only GCP is used for direct georeferencing, and Table 6 shows coordinate errors (X, Y, and Z) in data processing when the PPK method is used for georeferencing. Differences in coordinates obtained from 3D clouds and those obtained from static GNSS field measurements are defined as errors. When table 5 and table 6 are compared, UAV processing with the PPK method produces less error than processing without the PPK method, which is equal to 0.05. However, the results of UAV processing without PPK produced a smaller vertical error, which was equal to 0.001.

Table 7. Horizontal Total Error and CE90 Results

	Total Error (m)	**CE90**
Without PPK	0.013	0.020
With PPK	0.005	0.008

Furthermore, this study computes CE90 to determine horizontal accuracy in accordance with the BPN regulations of the Republic of Indonesia. According to table 7 of data processing without PPK has a total horizontal error of 0.013, resulting in a CE90 of 0.020, whereas data processing with PPK has a total horizontal error of 0.005, resulting in a CE90 of 0.008.

CONCLUSION

According to the findings of this study, the parameters chosen when processing UAV in data processing software affect the number of aligned, tie points, and dense clouds, with high accuracy parameters outperforming medium accuracy. Furthermore, georeferencing UAV data using the GCP and PPK-GNSS methods yields higher accuracy with a CE90 value of 0.008 m when compared to not using PPK, which yields a CE90 value of 0.02 m. In this case, according to the CE90 value on UAV using PPK and without PPK showed resulting photo map included in 1:1000 scale aerial photo map in class 1. However, georeferenced UAV data using the GCP and PPK methods has a 2.5 times higher data accuracy than data without PPK. As a result, PPK improves data accuracy and is more effective than without PPK. As a result, the UAV PPK-GNSS method is recommended for accelerating detailed land mapping in Indonesia.

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