Large Scale Mapping Using Unmanned Aerial Vehicle (UAV)-Photogrammetry To Accelerate Complete Systematic Land Registration (PTSL) (Case Study: Ciwidey Village, Bandung Regency, Indonesia)

S Hendriatiningsih\textsuperscript{1}, AY Saptari\textsuperscript{1}, A Soedomo\textsuperscript{1}, R Widyastuti\textsuperscript{1}, P Rahmadani\textsuperscript{1}, A Harpiandi\textsuperscript{1}

\textsuperscript{1}Surveying and Cadastre Research Science, Faculty of Earth Science and Technology, Institut Teknologi Bandung, 40132, Indonesia.

Email: shendriatin@gmail.com

Abstract. Technical Guidance for Complete Systematic Land Registration (PTSL) describes that implementation of PTSL requires a land registration base map for mapping of land parcels. The land registration base map uses aerial photo maps, high-resolution imagery maps, and vector maps. A PTSL was undertaken to solve overlapping problems. Currently, UAV can be used to accelerate mapping because the UAV system is able to observe the earth’s surface at low altitude and still fulfill the accuracy requirements of land mapping. To support the PTSL, a large scale land registration base map is needed, in this case will be done using UAV. Case study is located in Ciwidey Village, Bandung regency, which does not have base map of land registration, has hilly terrain, and ± 332 ha area. The method of making land registration base map is using UAV-photogrammetry method and Ground Control Point (GCP) measurement is done by using GPS-static method for base point measurement and using real-time-kinematic method (RTK) for GCP measurement. The analysis of the results of this large-scale mapping is using the standard of accuracy as recommended by American Society for Photogrammetry and Remote Sensing (ASPRS) 2014. The horizontal accuracy obtained from ortho-photo processing has fulfilled the ASPRS standard for 1: 1000 scale photo maps.

Keywords: Land Registration (PTSL), Large scale mapping, Aerial vehicle (UAV)

1. Introduction

One of the programs of the Ministry of Agrarian and Spatial Planning (ATR) / National Land Agency (BPN) is Complete Systematic Land Registration (PTSL) will be implemented to support economic growth. Complete Systematic Land Registration (PTSL) per village, subsequently upgraded at district and provincial levels (outside forest areas) is required to achieve the target by 2025. In order for the PTSL program to succeed, the steps to be undertaken by the Ministry of ATR / BPN including the acceleration of providing cadastral maps (1: 5000 scale and application of fit for purpose system) and Parcels Registration Number (NIB) and full juridical data (rural, district / city). The flow chart of the implementation of PTSL activities is as follows
Figure 1 explained that the availability of land registration base map on the implementation of this PTSL activity is very important. According to government regulation Number 24 year 1997, definition of the registration base map is a map containing technical base points and geographical elements, such as rivers, roads, buildings and physical boundaries of the land plots, but no map scale is defined. The Standard
on Manual for Cadastral Maps and Parcels Identifiers by 2016 provides the standardization of the required map scale as the basis for the map of the type of territory, as follows:

- Urban areas: 1: 1200 (1" = 100')
- Suburban areas: 1: 2400 (1" = 200')
- Rural areas: 1: 4800 (1" = 400') and 1: 9600 (1" = 800')

When referring to the IAAO of 2016, the scale of a good map used for this PTSL activity is at least 1: 1200. This was chosen because the activities of the PTSL were conducted in all types of areas, both in urban areas, rural, and suburbs. This research will describe how to obtain a baseline land registration map with efficient methods and tools but can produce a land registration base map for a 1: 1000 scale that standard horizontal precision adjusts to ASPRS 2014.

2. Methodology

The methodology that be used in this research can be described in Figure 2.

![Figure 2. Methodology]

Methodology can be described into step by step as follows:
2.1. Preparation
In this step, preparation of the equipment that being used, strip plan, and GCP distribution plan is needed for this research. The equipment that being used in this research is fixed wing Unmanned Aerial Vehicle (UAV) and SONY ILCE-6000 for the camera type. The GPS equipment type used Emlid Reach Rs. Figure 3 show the equipment that be used for this research.

![Figure 3](image)

**Figure 3.** The data acquisition equipment (a. Fixed Wing UAV, b. Camera ILCE-6000, c. GPS Emlid Reach Rs)

The strip plan must be conducted first before the next step. Strip plan accommodate 70% overlap and 60% sidelap rate. Total number of photos is 2,644 photos. Ground Control Point (GCP) distribution plan is needed to install the pre-mark that must be seen by the camera in the UAV equipment. The GCP distribution requirement was spread evenly in the Area Of Interest (AOI). Figure 4 show how the GCP distribution and Figure 5 show the pre-mark shape in the field survey. Figure 6 show how the Control Point (CP) distribution. Figure 7 show the example of CP measurement location using GPS static.
Camera specification is shown in Table 1.

| Camera Specification |
|-----------------------|
| Camera Model         | ILCE-6000   |
| Resolution           | 6000 x 4000 |
| Focal Length         | 35 mm       |
| Pixel Size           | 4.04 x 4.04 µm |

Average flying altitude is 338 m. Ground Sampling Distance (GSD) approximately 3.71 cm/pixel.

2.2. **Ground Control Point (GCP) and Check Point (CP)**

Number of GCP that being used in this research is 11. One base point being taken from Indonesian Geospatial Information Agency (BIG) benchmark in Padalarang area for four hours used static methods. Baseline distance from BIG benchmark to base point in Ciwidey is ±28 km. Ten GCP observed for ±1 hour for each GCP used Real Time Kinematic (RTK) method. Furthermore, check points observation used static method is also conducted along with GCP observation. The number of check point is 20 referring to ASPRS 2014 standard of accuracy. Measurement for all the points is in fixed solution. If the fixed solution not available when measured using GPS geodetic, the points must be moved to another location.

2.3. **Processing**

The first step processing in this research was GCP and CP processing. GCP will be used in the aerial photogrammetry processing and CP will be used to verify the data result. The second step is aerial data processing. The processing was using modern photogrammetry concept. The fundamental photogrammetric problem amounts to the determination of the interior and exterior orientation parameters of the camera and the coordinates of object space points measured on photos [1]. This photogrammetry concept was used for the processing in this research using Agisoft PhotoScan Software. The software ability has proven that the software is able to quickly produce the point cloud of the study area from the images taken by the non-metric camera [2]. Furthermore, the software indicate that the accuracy of the software in the process of
Triangulation is high compared to the Leica Photogrammetry Suite (LPS) software through the MRS outputs in terms of accuracy [3]. Therefore, this research was using Agisoft PhotoScan software because the number of aerial photo reach 2,644 photos.

Intrinsic parameter of interior orientation can be obtained from self-calibration methods using automatic tie points. Extrinsic parameter can be obtained from bundle adjustment processing. Bundle adjustment is the problem of refining a visual reconstruction to produce jointly optimal structure and viewing parameter estimates [4]. In order to maintain the quality of the processing, GCP as the control points were used in the aerial data processing.

2.4. Quality Control

Quality control was using standard of accuracy from ASPRS 2014. According to the standard of accuracy from ASPRS 2014, horizontal accuracy and vertical accuracy were based on the Root Square Mean Error (RMSE) of X, Y, and Z. The equation to calculate the RMSE of the digital planimetric data is as follows:

$$RMSE_X = \sqrt{\frac{\sum_{i=1}^{n} (X_{D_i} - X_{P_i})^2}{n}}$$  
(1)

Where:

- $RMSE_X$: X RMSE
- $X_{D_i}$: Coordinates X of the $i^{th}$ check point in the dataset
- $X_{P_i}$: Coordinate X of the $i^{th}$ check point in the independent source of higher accuracy
- $n$: the number of check points tested
- $i$: an integer ranging from 1 to n

$$RMSE_Y = \sqrt{\frac{\sum_{i=1}^{n} (Y_{D_i} - Y_{P_i})^2}{n}}$$  
(2)

Where:

- $RMSE_Y$: Y RMSE
- $Y_{D_i}$: Coordinates Y of the $i^{th}$ check point in the dataset
- $Y_{P_i}$: Coordinate Y of the $i^{th}$ check point in the independent source of higher accuracy
- $n$: the number of check points tested
- $i$: an integer ranging from 1 to n

$$RMSE_r = \sqrt{RMSE_X^2 + RMSE_Y^2}$$  
(3)

where

- $RMSE_r$: horizontal RMSE

Rule of standard of accuracy for map scale 1:1000 for horizontal accuracy can be seen in Table 2.
Table 2. Standard of accuracy for horizontal digital planimetric data.

| Horizontal Data Accuracy Class | Approximate Source Imagery GSD | RMSEx (cm) | RMSEy (cm) | RMSEr (cm) | Total number of Check Points |
|-------------------------------|-------------------------------|------------|------------|------------|-----------------------------|
| I                             | 10-20 cm                      | 12.5       | 12.5       | 17.7       | 20                          |
| II                            | 10-20 cm                      | 25.0       | 25.0       | 35.4       | 20                          |
| III                           | 10-20 cm                      | 37.5       | 37.5       | 53.0       | 20                          |

Horizontal class I products refer to highest-accuracy survey-grade geospatial data for more-demanding engineering applications, class II products refer to standard, high-accuracy mapping-grade geospatial data, and class III and larger class products refer to lower-accuracy visualization-grade geospatial data suitable for less-demanding user applications.

3. Result and Discussion

GCP coordinates, ICP coordinates, photogrammetry product and their accuracy will be discussed in this section. Table 3 show GCP coordinates and its accuracy. Table 5 show CP coordinates and its accuracy. Table 4 and 6 show average, maximum, and minimum of the standard deviation of X, Y, and Z of GCP and CP.

Table 3. GCP coordinates

| Check Point | Northing (m) | Easting (m) | Elevation (m) | Standard Deviation X (cm) | Standard Deviation Y (cm) | Standard Deviation Z (cm) |
|-------------|--------------|-------------|---------------|---------------------------|---------------------------|---------------------------|
| BM CWDY     | 772168.805   | 9214170.8   | 1107.277      | 0.1                       | 0.1                       | 0.9                       |
| CWDY 1      | 772399.007   | 9215085.2   | 1076.427      | 0.2                       | 0.3                       | 1.0                       |
| CWDY 2      | 772849.859   | 9214776.5   | 1074.676      | 0.2                       | 0.2                       | 0.5                       |
| CWDY 3      | 771873.388   | 9214529.6   | 1137.418      | 0.2                       | 0.3                       | 0.5                       |
| CWDY 5      | 771045.506   | 9214070.4   | 1170.317      | 0.2                       | 0.3                       | 0.6                       |
| CWDY 6      | 770890.43    | 9213491.3   | 1179.759      | 0.1                       | 0.1                       | 0.2                       |
| CWDY 7      | 769869.655   | 9214068.6   | 1221.347      | 0.4                       | 0.4                       | 1.8                       |
| CWDY 8      | 770380.147   | 9213015.6   | 1224.164      | 0.2                       | 0.2                       | 0.3                       |
| CWDY 9      | 769575.026   | 9213651.1   | 1262.555      | 0.4                       | 0.5                       | 1.2                       |
| CWDY 10     | 771607.514   | 9213642.4   | 1132.521      | 0.1                       | 0.1                       | 0.2                       |
| CWDY 11     | 770351.636   | 9213679.8   | 1222.096      | 0.2                       | 0.2                       | 0.6                       |

Table 4. Average, maximum, and minimum standard deviation of GCP.

|                      | Standard Deviation X (cm) | Standard Deviation Y (cm) | Standard Deviation Z (cm) |
|----------------------|---------------------------|---------------------------|---------------------------|
| AVERAGE              | 0.209                     | 0.245                     | 0.709                     |
| MAX                  | 0.4                       | 0.5                       | 1.8                       |
| MIN                  | 0.1                       | 1                         | 0.2                       |
Table 5. CP coordinates

| Check Point | Northing (m)  | Easting (m)  | Elevation (m) | Standard Deviation X (cm) | Standard Deviation Y (cm) | Standard Deviation Z (cm) |
|-------------|---------------|--------------|---------------|---------------------------|---------------------------|---------------------------|
| 1           | 9214453.442   | 772893.766   | 1103.432      | 0.18                      | 0.23                      | 0.15                      |
| 2           | 9214723.235   | 772518.289   | 1098.550      | 0.1                        | 0.14                      | 0.1                       |
| 3           | 9214109.947   | 772036.592   | 1133.201      | 0.05                       | 0.06                      | 0.04                      |
| 4           | 9214102.529   | 770840.882   | 1204.566      | 0.18                       | 0.24                      | 0.14                      |
| 5           | 9213939.097   | 769973.031   | 1247.800      | 0.09                       | 0.12                      | 0.08                      |
| 6           | 9213244.159   | 770656.177   | 1212.708      | 0.05                       | 0.06                      | 0.04                      |
| 7           | 9213773.665   | 771334.034   | 1170.460      | 0.02                       | 0.03                      | 0.02                      |
| 8           | 9213975.546   | 771605.590   | 1154.913      | 0.04                       | 0.06                      | 0.03                      |
| 9           | 9214514.003   | 772338.783   | 1111.773      | 0.06                       | 0.09                      | 0.05                      |
| 10          | 9214192.628   | 772303.523   | 1122.435      | 0.14                       | 0.18                      | 0.1                       |
| 11          | 9214557.122   | 772708.843   | 1102.583      | 0.11                       | 0.21                      | 0.14                      |
| 12          | 9214036.875   | 770335.387   | 1239.065      | 0.13                       | 0.18                      | 0.08                      |
| 13          | 9213989.228   | 771253.453   | 1177.349      | 0.06                       | 0.06                      | 0.04                      |
| 14          | 9213509.940   | 771020.654   | 1195.036      | 0.04                       | 0.05                      | 0.03                      |
| 15          | 9213771.323   | 770199.922   | 1247.275      | 0.17                       | 0.24                      | 0.1                       |
| 16          | 9213566.981   | 770619.544   | 1222.220      | 0.06                       | 0.07                      | 0.05                      |
| 17          | 9214292.473   | 772193.079   | 1123.018      | 0.16                       | 0.38                      | 0.18                      |
| 18          | 9214446.101   | 772802.693   | 1106.883      | 0.17                       | 0.2                       | 0.13                      |
| 19          | 9214043.666   | 771731.000   | 1149.376      | 0.04                       | 0.06                      | 0.03                      |
| 20          | 9213084.535   | 770448.470   | 1236.202      | 0.05                       | 0.06                      | 0.04                      |

Table 6. Average, maximum, and minimum standard deviation of CP

|                      | Standard Deviation X (cm) | Standard Deviation Y (cm) | Standard Deviation Z (cm) |
|----------------------|---------------------------|---------------------------|---------------------------|
| AVERAGE              | 0.095                     | 0.136                     | 0.0785                    |
| MAX                  | 0.18                      | 0.38                      | 0.18                      |
| MIN                  | 0.02                      | 0.03                      | 0.02                      |

GCP measurement was using RTK methods except for the base point (BM CWDY). Therefore, BM CWDY will be out for the discussion. The minimum value of standard deviation of GCP is 0.1 cm which is conducted from point CWDY 6 and CWDY 10. The location were open area like rice fields and far enough from the buildings. Figure 8 can show how the location condition.
The maximum value of standard deviation of GCP is 0.4 cm for X and 0.5 m for Y which is conducted from point CWDY 9. The location of point CWDY 9 was near the buildings. Figure 9 can show how the situation on the location.

Figure 8. Location of point CWDY 6 and CWDY 10

The maximum value of standard deviation of GCP is 0.4 cm for X and 0.5 m for Y which is conducted from point CWDY 9. The location of point CWDY 9 was near the buildings. Figure 9 can show how the situation on the location.

Figure 9. Location of point CWDY 9

CP measurement was using static methods. It is recommended from ASPRS. The minimum value of standard deviation of CP is 0.02 cm for X and 0.03 cm for Y which is conducted from check point number 7. The object that being measured was edge of the pathway. In this object, GPS stative can be stand up stable even though the location was near the buildings. Figure 10 show the situation of the location.

Figure 10. Location of check point number 7
The maximum value of standard deviation of CP is 0.02 cm for X and 0.03 cm for Y which is conducted from check point number 4 and 17. The location of check point number 4 is ditch border and near the buildings. The location of check point number 17 is fence and in the dense settlement. Figure 11 show the situation of the location.

![Figure 11. Location of check point number 4 and 17](image)

In the previous section, GCP were used in the bundle adjustment process to generate the accuracy of GCP. Table 7 show the accuracy of GCP from the bundle adjustment process. Average XY error is 0.00351 cm.

**Table 7. The accuracy of GCP from bundle adjustment process**

| ID    | Standard deviation X and Y (cm) | Standard deviation Z (cm) |
|-------|---------------------------------|---------------------------|
| BM CWDY | 0.0265                          | 0.015                     |
| CWDY 1   | 0.014                           | 0.005                     |
| CWDY 2   | 0.0199                          | 0.0002                    |
| CWDY 3   | 0.0309                          | 0.0125                    |
| CWDY 5   | 0.0541                          | 0.0115                    |
| CWDY 6   | 0.038                           | 0.0059                    |
| CWDY 7   | 0.0313                          | 0.0134                    |
| CWDY 8   | 0.0253                          | 0.0037                    |
| CWDY 9   | 0.014                           | 0.0196                    |
| CWDY 10  | 0.0497                          | 0.0059                    |
| CWDY 11  | 0.0741                          | 0.0002                    |

Figure 12 and Figure 13 show the orthophoto maps and Digital Surface Model (DSM).
Quality control of the product was using standard of accuracy ASPRS 2014. The result of this research is digital planimetric data for Complete Systematic Land Registration (PTSL). Horizontal accuracy is more important than the vertical accuracy in this case. So, the vertical accuracy will not be discussed in this research. The comparison of accuracy from ASPRS 2014 and the result of orthophoto map can be shown in Table 8.
Table 8. Comparison the result and the standard accuracy of ASPRS 2014

| Information                         | Approximate Source Imagery | GSD | RMSE<sub>x</sub> (cm) | RMSE<sub>y</sub> (cm) | RMSE<sub>r</sub> (cm) | Total number of Check Points |
|-------------------------------------|----------------------------|-----|-----------------------|-----------------------|-----------------------|-----------------------------|
| ASPRS 2014                          | Map Scale 1:1000, class of accuracy = 1 | 10-20 cm | 12.5                  | 12.5                  | 17.7                  | 20                          |
| Orthophoto maps of Ciwidey Village  | 1:1000                     | 3.71 cm  | 5.34                  | 5.74                  | 7.84                  | 20                          |

Table 8 described that the RMSE<sub>x</sub> and RMSE<sub>y</sub> of the result of orthophoto map under 12.5 cm. RMSE<sub>r</sub> of the result of the orthophoto map is also under 17.7 cm. This means the result of this research fulfilled the standard accuracy for the horizontal digital data.

4. Conclusion
The UAV-photogrammetry methods for large scale mapping to accelerate Complete Systematic Land Registration (PTSL) has fulfill the horizontal standard of accuracy from ASPRS 2014. The product is in 1:1000 scale map. The distribution of the Ground Control Point (GCP) and Check Point (CP) is spread evenly in the research area. The GCP measurement was using static methods for base point and Real Time Kinematic (RTK) methods for the rest. The best result for the GCP location is in open area and far enough from the building. CP measurement was using static methods. The object selection to measure is important for the result of quality control. There are edge of pathway, fence, and bridge. It is important that the location from the orthophoto maps must be installed in the exact same location. The location situation is also important which are in the open area and far away from the buildings. GCP were used in the bundle adjustment processing and CP were used for the quality control of the orthophoto maps.

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