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The Usability of Unmanned Aerial Vehicle (UAV) for Land Cadastral Registration in Indonesia

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Abstract

The ministry of Agrarian and Land Use Planning/ National Land Agency (NLA), which has the authority to manage the land in Indonesia, targeted to register all land parcels in 2025. However, measuring of land parcels using existing method costs a lot of money, needs a long time, and it might require several years to be completed. The measuring of land parcels is also influenced by the type of land landscapes, topography, and the number of land officers involved. Unmanned Aerial Vehicle – a tool which does not depend on the human physical capabilities – is seen as an alternative method to accelerate the land measurement. This research objective is to investigate whether UAVs can be used to replace the terrestrial methods for land registration that is conducted in Bengkulu Tengah and Bogor. To do so, first, a meeting with local authorities had been conducted. This step is required to know the responses and ask the permissions before conducting research. Second, performing land measurement using UAV method, participatory boundary mapping, and interviews with local communities and UAV's pilots. Third, an evaluation is carried out to compare the duration, cost, accuracy, and participatory boundary mapping of the new method with the conventional one. Even though the low accuracies occurred in unclear boundary parcels, the result shows that measuring with UAVs takes less time and has lower costs compared with the conventional method.

Keywords: UAV, Participatory Boundary Mapping, Bengkulu Tengah, Bogor

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1. Introduction

As mentioned in article 33 clause 3 in Indonesia's constitution of 1945, "land, water and natural resources contained therein controlled by the National Government and used for the prosperity of the people", the authority to manage the land in Indonesia is given to the Ministry of Agrarian and Land Use Planning/ National Land Agency (NLA) (Presidential Decree No.20/2015, 2015). The total land area in Indonesia is 192,000,000 Ha. NLA manages only 35,07% or 67,080,000 Ha, while the rest of it is under the authority of Forest Ministry (National Land Agency (NLA), 2014).

The NLA's authority includes land right and land registration (Indonesia's Government Regulation No. 24/1997, 1997). These activities consist of land parcel measurements, surveying and mapping, and issuing the land tenure certificate for individuals, private businesses, and government. In order to perform the duties, NLA is divided into three levels; sectoral level (municipality) – 436 of municipalities land offices, regional level (province) – 34 of regional land offices, and national level (head office) (Astanto, 2016). In 2007, the Government issued the Agrarian Reform Program. One of the program objectives is all of the land parcels in Indonesia have to be measured and registered by 2025 (Sumarto et al., 2008).

Until 2016, only 18,601,008 Ha or around 42,000,000 land parcels have been registered (Education and Training Centre NLA, 2016). To reach the rest, NLA uses the newest terrestrial measurement tools (e.g. GNSS rover, GPS geodetic, etc.). With only 2,780 land officers, it seems impossible to measure the rest of unregistered land parcels and achieve the program target. To accelerate it, NLA needs a tool or a method which does not depend on the human physical capabilities. In the Regulation of Ministry Agrarian and Land Use Planning/ NLA No. 3/1997 (1997), it is stated that the surveying and mapping for land registration can use the terrestrial, photogrammetry, or other methods (Minister of Agrarian/ NLA Regulation No. 3/1997, 1997).Therefore, UAVs (Unmanned Aerial Vehicles) – seems as a promising tool.

1.1 Problem Statement

Since introduced by military in 19's century, Unmanned Aerial Vehicles (UAVs) have started being used for civil activities. Because it has various benefits, many studies apply UAVs for several purposes, including for land cadastral registration. Ramadhani (2016) mentioned that UAVs can be applied to determine boundaries of rice fields in West Nusa Tenggara, Indonesia (Ramadhani, 2016). This is also stated by Silalahi et al., (2016) who use it for mapping the district boundaries in Indonesia (Silalahi et al., 2016). In addition, Sadikin et al., (2014) agree that this unmanned vehicle can be applied to solve geometric accuracy problem, as a solution to map land parcels in rural areas which have few of transportation facility. It also can be used to provide spatial data for land administration to identify the assets (Sadikin et al., 2014). In the other countries, UAVs have been used for cadastre. In Netherlands, it was used for juridical verification of cadastre border for real-estate (Rijsdijk et al., 2013). Alaska State-USA and Poland also applied it to update cadastre maps and for taxation purposes (Cunningham et al., 2015).

Land cadastral registration in Indonesia takes a long time and is expensive. The driven factors that influence this condition are the topography, tools, and the community participation to determine the land parcels. Therefore, this study to investigate the usability of UAVs to support the land cadastral registration and focuses on comparing it to terrestrial methods, looking at accuracy, cost, and time.

1.2 Research objectives and research questions

The objective of this research is to investigate whether UAVs can be used to replace the terrestrial methods for land registration. In order to reach the research objective, several research questions were formulated as mentioned below:

Q1: How many parcels can be mapped per day with different surveying methods?

Q1.2: How long does it take for the different type of landscapes?

Q2: How much does it cost in time and money to map a parcel compared to GNSS rover and GPS Geodetic?

Q3: What is the accuracy of the UAVs based map?

Q4: What are the issues encountered when combining UAV surveying in combination with participatory mapping?

2. Theoretical background

2.1 UAV – overview

2.1.1 Definition and classification

Unmanned Aerial Vehicle (UAV) has variously been referred to the different contexts and aviation jurisdictions. For instance, Unmanned Aerial System (UAS), Remotely-Piloted Aerial Systems (RPAS), Aerial Robots, or Drones (Turner et al., 2016). It also has several definitions. According to American Institute of Aeronautics and Astronautics (AIAA) (2014) cited in Muryamto et al., (2014) UAV is an aircraft which is designed not to carry the human pilot (Muryamto et al., 2014). It can bring a camera, sensor, communication equipment, and other tools which make them function as remote sensing device (e.g. the electromagnetic sensor system, biological sensor, and chemical sensor) (Andaru & Purnama, 2015)

This unmanned vehicle can be remotely controlled, semi-autonomous, autonomous, or a combination of them (Bento, 2008), and allow flexible manoeuvrings (Crommelinck et al., 2016). Therefore, it has a lot of advantages and very useful to public power utilities, for instance for assessing storm damage, surveying distribution and transmitting equipment, and supporting construction and repair (APPA, 2016). It is also used for intelligence, surveillance, and reconnaissance (SR) activities (Andaru & Purnama, 2015). Banard Microsystem Limited (2011) cited in Shofiyati (2011) argues that this tool can be operated anytime; it can fly at low altitude which resulted in high resolution and accuracy (ranging from a meter to centimetre level); the price is relatively cheaper than the other manned vehicles; and it is more environmentally friendly (Shofiyanti, 2011). Nevertheless, UAVs pose a threat to electric system equipment when operated by others (APPA, 2016), need a high cost in first instalment (Shofiyanti, 2011), have a limitation in flight endurance and stability (Ramadhani, 2016), and have uncertain or restricted airspace regulations (Crommelinck et al., 2016).

In general, there are three components of UAVs: airborne components (vehicle, camera, battery, gimbal, etc.), ground-based components (base station or laptop), and radio control transmitter to control the UAV. Airborne components carry the equipment. Laptop or base station is used to prepare initial flight planning and show the real-time navigation, imagery, and telemetry information. In addition, remote control transmitter is used to facilitate data transfer and instruction from and to the UAV.

UAVs are divided into two categories: multi-rotor or VTOL (Vertical Take Off and Landing), and fixed wing (figure 1). Multi-rotor designed with 3 or 4 – quadcopters, 6 – hexacopters, and 8 propellers – octocopters. Both are also designed in different weight, range, speed, and purposes. Due to the lack of UAV international standard certification, The European Association of Unmanned Vehicle Systems (EUROUVS) divides the type of UAVs based on flight altitude, endurance, speed, maximum take-off weight (MTOW), and size as shown in table 1. Based on that, DJI phantom IV which is used in this research refers to a tactic group.

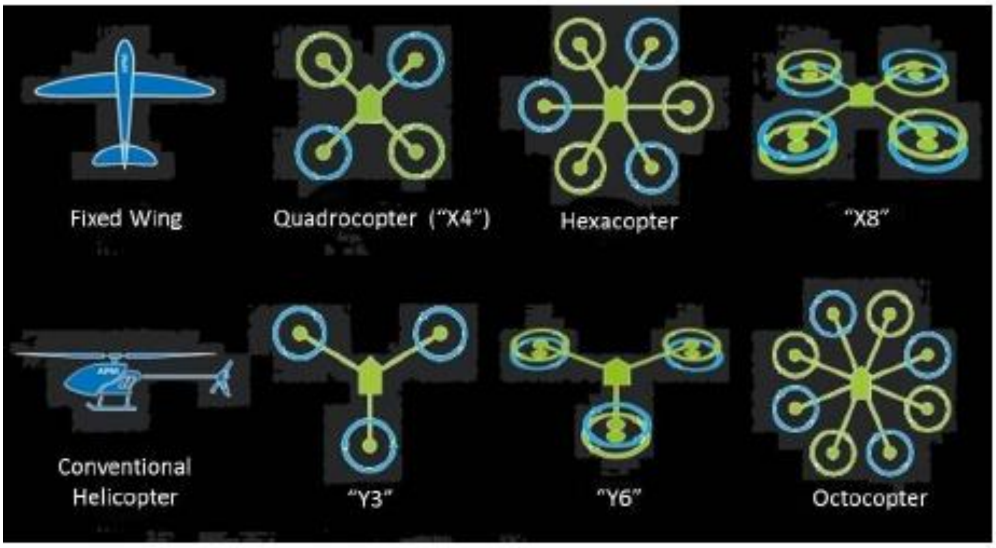


Figure 1. common UAV platforms. source: (Barnes et al., 2014).

Table 1. Classification of UAV types

Source: Adapted from a EUROUVS publication cited (Bento, 2008)

	Category (acronym)	Maximum Take Off Weight (kg)	Maximum Flight Altitude (m)	Endurance (hours)	Data Link Range (Km)	Example	
						Missions	Systems
Micro/Mini UAVs	Micro (MAV)	0.10	250	1	< 10	Scouting, NBC sampling, surveillance inside buildings	Black Widow, MicroStar, Microbat, FanCopter, QuattroCopter, Mos-quito, Hornet, Mite
	Mini	< 30	150-300	< 2	< 10	Film and broadcast industries, agriculture, pollution measurements, surveillance inside buildings, communica-tions relay and EW	Mikado, Aladin, Tracker, DragonEye, Raven, Pointer II, Carolo C40/P50, Skorpio, R-Max and R-50, Robo-Copter, YH-300SL
Tactical UAVs	Close Range (CR)	150	3.000	2-4	10-30	RSTA, mine detection, search & rescue, EW	Observer I, Phantom, Copter 4, Mikado, RoboCopter 300, Pointer, Camcopter, Aerial and Agricultural RMax
	Short Range (SR)	200	3.000	3-6	30-70	BDA, RSTA, EW, mine detec-tion	Scorpi 6/30, Luna, SilverFox, EyeView, Firebird, R-Max Agri/ Photo, Hornet, Raven, phantom, GoldenEye 100, Flyrt, Neptune
	Medium Range (MR)	150-500	3.000-5.000	6-10	70-200	BDA, RSTA, EW, mine detec-tion, NBC sampling	Hunter B, Mücke, Aerostar, Sniper, Falco, Armor X7, Smart UAV, UCAR, Eagle Eye+, Alice, Extender, Shadow 200/400
	Long Range (LR)	-	5.000	6-13	200-500	RSTA, BDA, communications relay	Hunter, Vigilante 502
	Endurance (EN)	500-1.500	5.000-8.000	12-24	> 500	BDA, RSTA, EW, communica-tions relay, NBC sampling	Aerosonde, Vulture II Exp, Shadow 600, Searcher II, Hermes 450S/450T/700
	Medium Altitude, Long Endurance (MALE)	1.000-1.500	5.000-8.000	24-48	> 500	BDA, RSTA, EW weapons delivery, communications relay, NBC sampling	Skyforce, Hermes 1500, Heron TP, MQ-1 Predator, Predator-IT, Eagle-1/2, Darkstar, E-Hunter, Dominator
Strategic UAVs	High Altitude, Long Endurance (HALE)	2.500-12.500	15.000-20.000	24-48	> 2.000	BDA, RSTA, EW, communica-tions relay, boost phase intercept launch vehicle, airport security	Global Hawk, Raptor, Condor, Theseus, Helios, Predator B/C, Libellule, EuroHawk, Mercator, SensorCraft, Global Observer, Pathfinder Plus,
Special Task UAVs	Lethal (LET)	250	3.000-4.000	3-4	300	Anti-radar, anti-ship, anti-aircraft, anti-infrastructure	MALI, Harpy, Lark, Marula
	Decoys (DEC)	250	50-5.000	< 4	0-500	Aerial and naval deception	Flyrt, MALD, Nulka, ITALD, Chukar
	Stratospheric (Strato)	TBD	20.000-30.000	> 48	> 2.000	-	Pegasus
	Exo-strato-spheric (EXO)	TBD	> 30.000	TBD	TBD	-	MarsFlyer, MAC-1

2.1.2 Regulation of UAV in Indonesia

In Indonesia, UAVs have existed since 2000. Afterwards, several type of researches using UAVs have been conducted by academic, public, and private sectors. To limit the uses, Indonesia's Government through the Ministry of Transportation issued a regulation No. PM 90/2015. On this policy, the public is allowed to operate UAVs below 500 feet or 150 m, and it is not permitted in prohibited area, restricted area, and controlled the airspace area. Cooperation, permission, and flight license from the flight navigation unit are required if the UAVs will be operated above 500 feet or 150 m. The permission of UAVs should be submitted to Ministry of Transportation at least 7 days before the operation is started. Whilst, to get the UAV's flight license, it should be proposed at least 14 working days. This policy also regulates the penalty if the users of UAVs violate the rule (Indonesian Ministry of Transportation Regulation No PM 90/ 2015, 2015).

2.2 Land Cadastral Registration in Indonesia

According to Irwansyah et al., (2013), land cadastral registration in Indonesia is a method to manage and to inventory the legal land data in a certain area based on boundaries survey. It has a fundamental function to support national development, especially in economic, agriculture, nature conversation, and social sectors. Based on the type, cadastre is divided into fiscal, legal, and multi purposes cadastre. Whilst, on the dimension, it is classified into marine and land cadastre (Irwansyah et al., 2013).

Land registration in Indonesia adopts the negative system. In this system, there is no guarantee regarding the actual land owner certificates. If any people have the evidence, the certificate could be repealed (Damanhury, 2012). Based on the land ownership, land tenure rights are divided into two parts: public and civil law rights, and "*ulaya*t" rights – the terms for community properties. There are six objects of land registration: personal rights, cultivate rights, building and use rights, management rights, waqf – granted for religious purposes, apartment rights, mortgage rights, and state rights (Indonesia's Government Regulation No. 24/1997, 1997). The land registration is implemented in two ways: systematic and sporadic. In a systematic way, registration is carried out on all plots (mass) which is covering the villages, whereas, in sporadic way, it is based on the request concerned individual or in bulk (Yamin & Lubis, 2009).

2.2.1 Methods and delineation boundary on land cadastral registration

As listed in clause 12 of Minister of Agrarian/NLA regulation No. 3/ 1997, the methods of surveying and mapping that used to perform the registration of basic mapping are terrestrial, photogrammetric and other measurements. The tools that are used in terrestrial method consist of tape, Electronic Distance Meter (EDM), theodolite, total station, GPS receiver, and GNSS RTK. Whilst, in photogrammetric method, the scale of photo map should at the range between 1:200 and 1: 1000. Satellite imagery is the one of methods that can be used in other measurement methods.

The registration of basic map should be in basic framework of the national system. In Indonesia, the coordinate system used is National Transverse Mercator with width zone 3° known as TM 3° (appendix 1) (Minister of Agrarian/ NLA Regulation No. 3/1997, 1997).

Delineation on cadastral boundaries

The aim of delineation of cadastral boundaries is to mark the boundary on every corner of the land parcels. The neighbours presence are required due to the claimant and agreement of the land parcel's boundaries. Afterwards, the land owner should provides boundary markings, which are planted in every corner of the land parcels, that will be surveyed. The size of boundary markings is divided by the size of the area: less than 10 Ha and more than 10 Ha as shown in Table 3. The boundaries can be placed with fixed-built up materials, for example fences, wired fences, concrete walls, etc.

Table 2. The size of boundary markings
Source: (Ramadhani, 2016).

<10 Ha	**>10 Ha**
Metal pipe/ pipe rod length ≥100 cm, diameter ≥ 5cm;	Metal pipe length ≥ 1.5 m, diameter ≥10 cm
Pipe contained concrete materials length ≥ 100 cm, diameter ≥ 5 cm	Iron block length ≥ 1.5 m, diameter ≥ 10 cm;
Iron wood/ teak length ≥ 100 cm, width ≥7.5 cm	Iron wood/ teak length ≥ 1.5 m and width ≥ 10cm;
Brick monument sized ≥ 0.20x0.2x0.4 m;	Brick monument sized ≥ 0.30x0.30x0.60 m;
Concrete materials monuments sized 0.1x0.5x0.4 m	Piped contained concrete materials length ≥ 1.5 m, diameter 10 cm.

2.2.2 Duration and Cost

NLA is divided into sectoral or municipality (*Kantor Pertanahan*), province (*Kantor Wilayah*), and national level. The classifications are based on the different level of authority on the size of the measurement area. Less than 2 Ha area is under the sectoral authority, >2 Ha <2000 Ha is under the province, and more than 2000 Ha is under the head office jurisdiction (Minister of Agrarian/ NLA Regulation No. 3/1997, 1997). The duration of measuring the land cadastral registration is around 12 – 30 days (Head of National Land Agency Regulation No. 1/ 2010b, 2010). Whilst, the fees for land registration are regulated in Government Regulation No. 128/ 2015 as shown in Table 3.

Table 3. formula to calculate the measurement rate and mapping services
source: (Indonesia's Government Regulation No. 128/2015, 2015)

Large of Area	**Formula**
0 - 10 Ha	$Tu = \left(\frac{L}{500} \times HSBKu \right) + Rp100.000,00$
10 – 1000 Ha	$Tu = \left(\frac{L}{4.000} \times HSBKu \right) + Rp14.000.000,00$
>1000 Ha	$Tu = \left(\frac{L}{10.000} \times HSBKu \right) + Rp134.000.000,00$

As shown in table 3, Tu is the fee for each land parcel that conducted in a sporadic way. L is the size of land parcel (Ha) which will be surveyed. HSBKu is the unit price for the special fee in surveying, and the price is different depending on the province (see appendix 2).

Meanwhile, Rp 100,000.00; Rp 14,000,000.00; and Rp 134,000,000.00 are the determined price in Indonesia currency (Rp). The fee for mass cadastral survey/systematic way is 75% of the value computed using the similar formula.

2.3 UAV for land cadastral registration in Indonesia

Based on land use, the map scale is divided into three: less than 1: 1,000 for the residential area; below 1: 2,500 for agricultures; and 1: 10,000 for plantation purpose (Minister of Agrarian/NLA Regulation No. 3/1997, 1997). To obtain the results in those map scale, the XY accuracy residual means square error (RMSE) should below 2.5 m (table 4).

Table 4. Relation among GSD, map scale, XY accuracy, and contour interval
source: (Bramantio and Hidayat 2016)

MAP Scale	Map Standard		Comparison film photographs	
	X-Y accuracy RMSE (m)	Contour interval (m)	photo scale	pixel size on ground of scanned film (cm)
1:500	0.125	0.25	1:3,000 - 1: 5,500	2.5 - 5
1:1,000	0.25	0.5	1:5,000 – 1: 8,000	5 - 7.5
1:1,500	0.4	0.75	1:6,500 - 1: 10,000	7.5 - 10
1:2,000	0.5	1	1:8,000 - 1: 11,000	10 - 15
1:2,500	0.6	1.25	1:8,500 - 1: 13,000	12.5 - 17.5
1:5,000	1.25	2.5	1:12,000 - 1: 18,000	15 - 25
1:10,000	2.5	5	1:17,000 - 1: 27,000	20 - 30
1:20,000	5	10	1:25,000 - 1: 35,000	25 - 35
1:25,000	6.25	12.5	1:28,000 - 1: 42,000	25 - 40
1:50,000	12.5	20	1:40,000 - 1: 60,000	25 - 50
1:100,000	25	50	1:60,000 - 1: 90,000	25 - 50

2.4 Participatory Mapping

Participatory mapping is an approach to represent spatial knowledge of communities by combining tools of modern cartography and participatory methods (Rainforest Foundation UK, 2016). Broadly, it can illustrate social interest, cultural interest, and historical knowledge such as information related to land use, demography, ethnolinguistic groups, health patterns and wealth distribution. This participatory mapping has a function to identify traditional lands and resources, as a mechanism to secure tenure and help the legal recognition of customary land rights and boundaries (IFAD, 2009).

According to the International Fund for Agriculture Development (IFAD) (2009), there are five principle tools of participatory mapping: hands-on mapping, scale maps and images, and participatory 3-D models, participatory Geographic Information Systems (PGIS), and multimedia and Internet-based mapping. *Hands-on mapping* is basic mapping method. The community draws the maps based on their memories on the ground and piece of paper. This technique is inexpensive, not requiring technology, and low-resource-input activities. The higher level of participatory mapping is using *scale maps and images* which are based on a discussion with the community. Then, they draw the sign of land parcel boundaries onto a photocopied map or remote-sensed map. The participatory mapping using scale maps and images has a coordinate system and projection. It needs several types of equipment, such as compass and GPS. However, this approach is relatively cheaper and faster than hands-on mapping participatory. Therefore, this type of participatory mapping is a suitable format for the government to decide the land ownerships and boundaries of land parcels. *The participatory 3-D modelling* integrates the community spatial knowledge and the data on land including elevation, scaled, and geo-referenced models. Since the maps have a high detail, a large part of the community needs to be involved. Whilst, *participatory GIS (PGIS)* uses GIS technology to store, retrieve, analyse, and present the land spatial information. *Multimedia and Internet-based mapping* is combined of spatial learning, communication and advocacy (IFAD, 2009).

In Indonesia, to define the land parcel boundaries is used the participatory scale maps and images called *contradictore delimitatie*. As regulated on Indonesia's Government Regulation No. 24/1997 (1997), *contradictore delimitatie* is a fundamental requirement in land cadastral registration. The land owners must show the land parcel boundaries and it has to be agreed by their neighbours. Afterwards, the land owners must install the boundary markers on every corner (Indonesia's Government Regulation No. 24/1997, 1997).

3. Methodology

3.1 Material

To reach the research objective, this research uses several of equipment and data:

1. UAV: *DJI phantom IV;*
2. *Instruments: Leica GNSS Receiver; Ipad/ Smartphone*; Laptop/ Computer Desktop;
3. Software: *DJI GS Pro; Menci aps (free use can be accessed at:* http://www.menci.com/it/*); Agisoft Photo-Scan; ArcGIS 10.5;*
4. Personal: licensed pilots and NLA officers;
5. Existing data : data of land parcel boundaries (coordinates and areas) which are measured by terrestrial methods from land offices of Bengkulu Tengah and Bogor; budget report of the national document of Indonesia.

This equipment and data are available at NLA, and the private companies.

3.2 Study Area

This research is located in three areas: Bengkulu Tengah, Bogor, and West Jakarta. The study areas were chosen based on the following criteria: number of registered parcels, type of landscapes, and non-conflict area.

Bengkulu Tengah

Bengkulu Tengah lies in the south west of Sumatera Islands. It is located 102°11'24"-102°37'12" E and 3°28'48" - 3°51'36" S. The study area was located in the sub district of Nakau and Karang Tengah (figure 2). The size area of Nakau is 9,362 Ha, while Karang Tengah has 13,747 Ha. Nakau is more crowded sub-district than Karang Tengah, which is inhabited by around 13,100 people, whereas the population in Karang Tengah is only 11,406 people habitants (Central Bureau of Statistics of Bengkulu Tengah, 2012). Mostly, the land covers are dominated by personal and private palm oil plantations (39%), mixed plantation (23%), and forest (18%). The rest is the residential and rice fields area (Environmental Agency of Bengkulu's Province, 2014). Therefore, the sampling study area in Karang Tengah is personal mixed and palm oil plantation, whereas in Nakau consists of residential area, field rice, personal mixed and palm oil plantation.

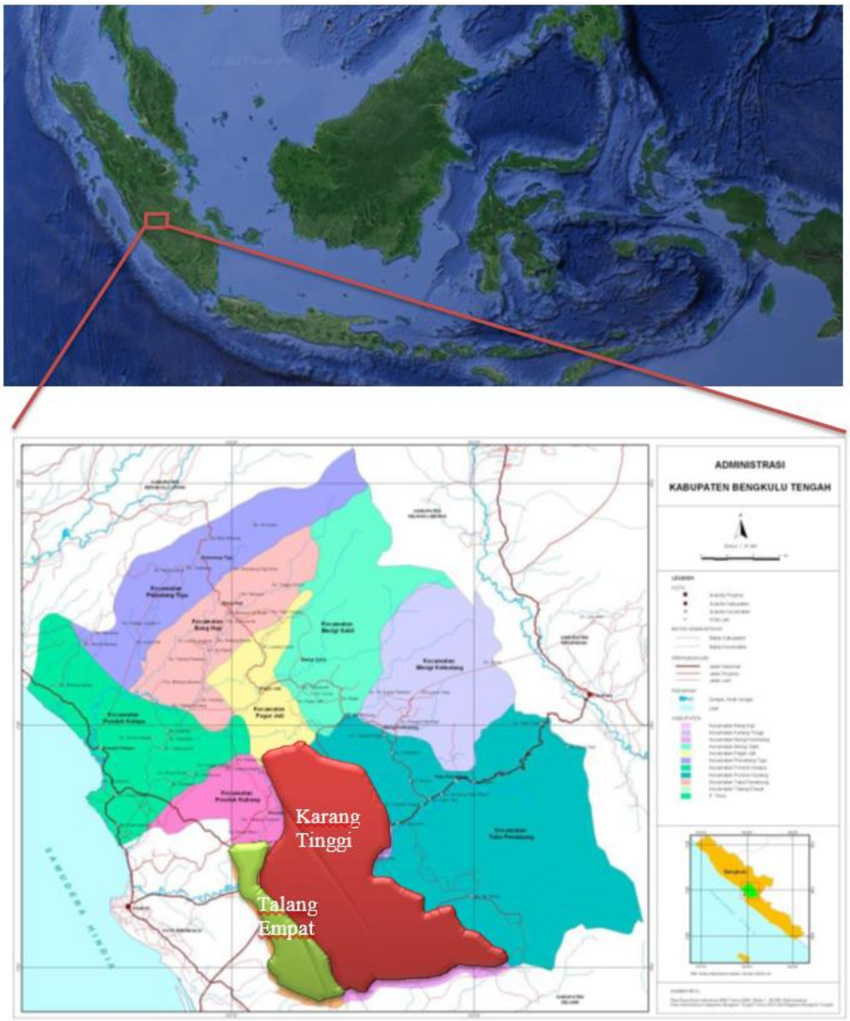


Figure 2. Study area 1: Talang Empat and Karang Tinggi districts, Bengkulu Tengah.
Source: (Government of Bengkulu Tengah, 2017).

Bogor

The second area is located in Waru Village, Parung District, Bogor in West Java. The sub district is located in 106°72'31"E and 6°42'44"S (figure 3). This village covers only 291 Ha, with a population of around 16,600 people, it is predicted that it will increase in size (Bogorkap.go.id, 2017). The distance of Bogor to Jakarta, the capital city of Indonesia, is around 40 km, so many people who work in Jakarta live in this city (Government of Bogor City, 2014). As a consequence, Bogor has developed as a satellite city or a sub urban area. Hence, the second reflects a sub urban area which still has the clear boundaries residential area, public facilities, water fish ponds, and open fields.

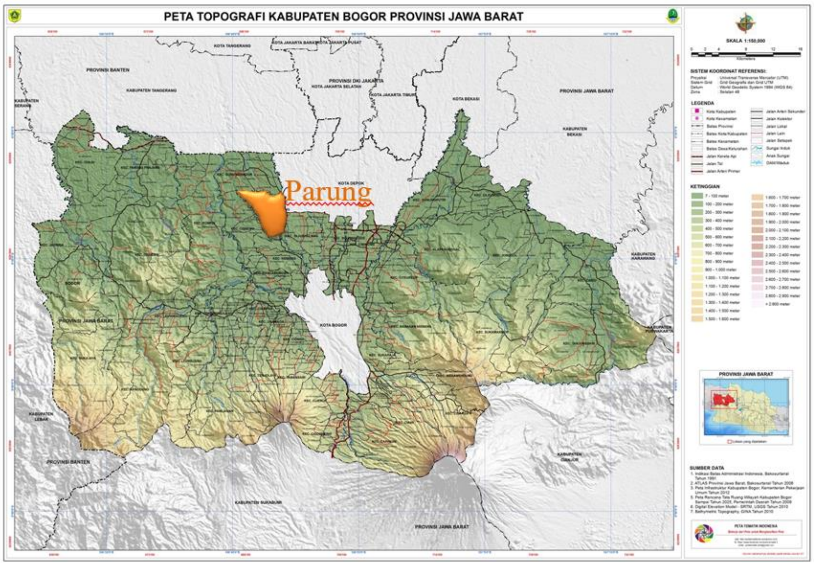


Figure 3. Study area 2: Parung district, Bogor.
Source: (Designmap Peta Tematik Indonesia, 2016)

West Jakarta

The last study area is in Kembangan district, West Jakarta (figure 4). This area covers 241,600 Ha and it is inhabited by around 391,000 people with a population growth of 4% per year (Central Bureau of Statistics of West Jakarta, 2016). As one of districts in capital city, Kembangan has a rapid growth, especially in the residential areas. Land office of West Jakarta state that there are 3,706 land parcels in Kembangan district which consist of residential areas, apartments, shopping centres, and office buildings (kkp.bpn.go.id, 2017). Thus, this region is chosen to reflect the residential housing in urban area.

Figure 4. Study area 3: Kembangan district, West Jakarta. Source: (petatematikindo, 2015).

3.3 Flow chart

The flow work of this research is shown in figure 5.

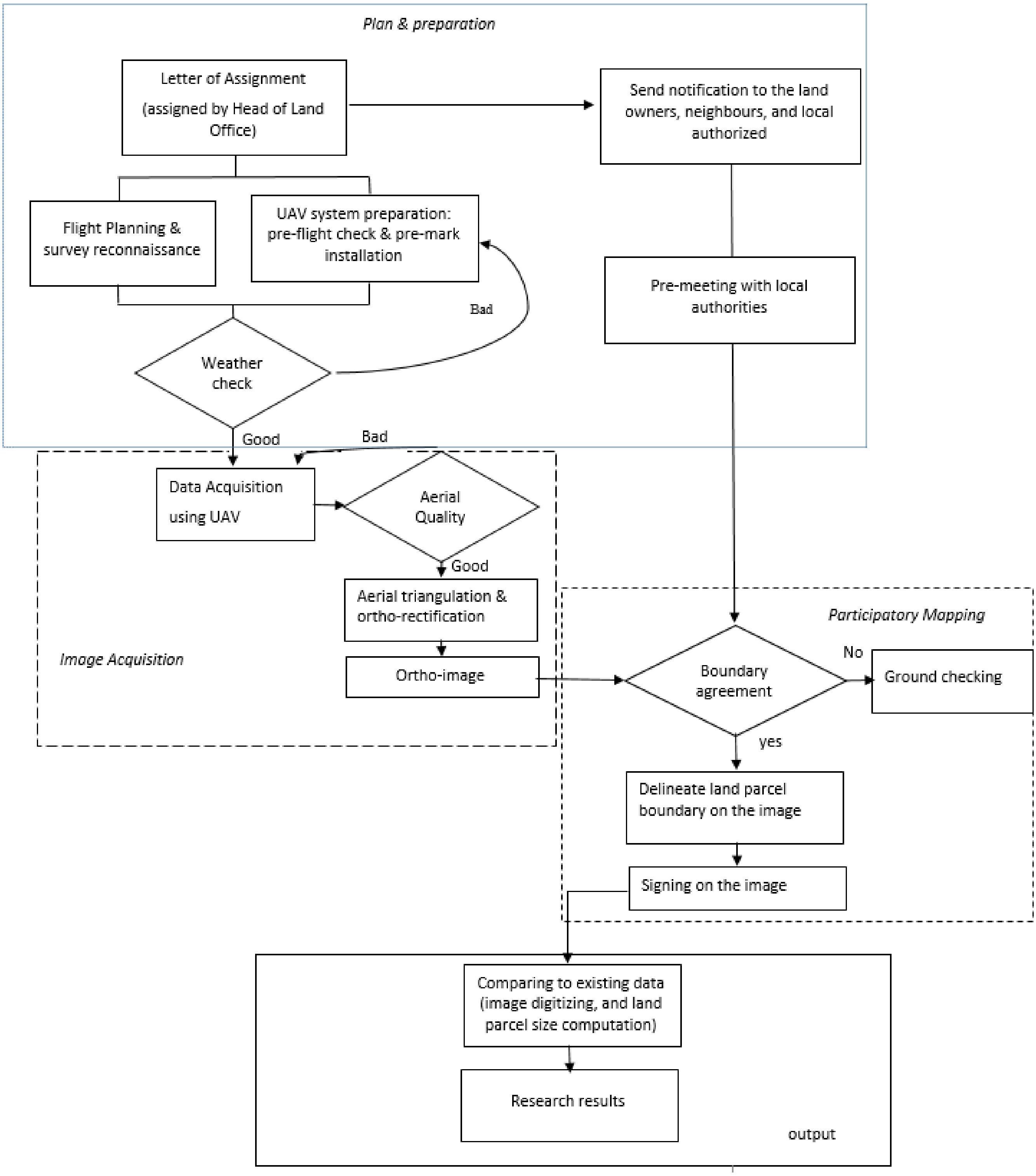


Figure 5. Research of flow work

The flowchart is starting with preparing the letter assignment and ends up with the research result. To address the research objective, a presentation of the overall methodology is constructed. Details about the methodologies of this research will be explained in different sub-chapters.

3.3.1 Plan and preparation

Letter assignment

The administration letters are the important things before the research is conducted. It was signed by the head of the land office of Bengkulu Tengah, Bogor, and West Jakarta. Then, it is sent to the land owners, neighbours, and local authorised. These letters are a permission to conduct the research.

Flight planning and survey reconnaissance

A survey reconnaissance was conducted to get an overview of the location and to prevent dangerous obstructions such as cell towers, prohibited area, power lines, etc. This survey was also used to investigate and define the areas where to make the GCPs.

Pre-flight check and pre-mark installation

In this stage, the GCP markings were created and installed in the field. The distribution of GCPs was created using images from google earth. The total GCPs in the first areas was 13 points that spread in the whole area of Nakau (7 points), and the rests were in Karang Tengah. In addition, GCPs in Waru was only 6 points. The marking used a white-crossed marking made of plastic and coloured with the black as shown in figure 6.

Figure 6. Pre-mark installation

3.3.2 Image acquisition

Fieldwork

The first step in field data collection was measuring the GCPs. Due to the first study area was in the remote area and it was unreachable from CORS network, the tool that used was GPS Geodetic (figure 7.). In Nakau, the measurement of GCPs took a half day for 50 Ha, while in Karang Tengah was 1 day for 40 Ha. The topography and weather were the main factors of GCPs measurement in Karang Tengah which took extra time. The total points in Nakau were 7, whereas Karang Tengah was 8 points, included the one base. At the second area, Waru sub-district used GNSS RTK (figure 8.), the GCPs measurement only less than an hour for 60 Ha.

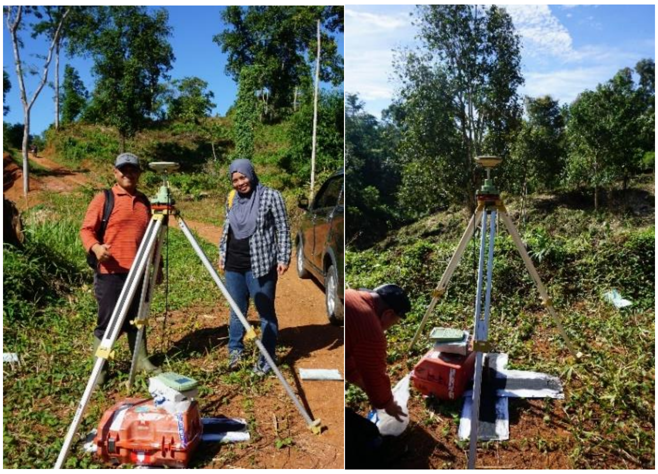


Figure 7. GCPs measuring used GPS Geodetic.

Figure 8. GCPs measuring used GNSS RTK.

Before the field data collection was conducted, a trial flight to test the connection between UAV and the ground station (remote) were carried out. The UAV used in this research was DJI Phantom IV (figure 9). In this step, DJI GS Pro software was used to capture and maintain the mission's flight path.

Figure 9. DJI Phantom IV used for research.

The next step is defining the flight parameters. It includes the height, frontal and side overlap, and the size areas captured. In the first areas (Nakau and Karang Tengah), the heights were 110 m and 122 m, while the height on second area (Waru) was 100 m. With the frontal overlap and side overlap for both areas were 85% and 43% respectively. The trial and field data collection were done within two days due to the bad weather and heavy rain. The trial flight was conducted only in 1 time. To capture the area (50 Ha for Nakau, and 40 Ha for Karang Tengah) the UAV should flight three times. Whilst, in Waru, it flew 5 times. Each flight took around 20 minutes. The image acquisitions resulted 652 and 1087 images for Nakau and Karang Tengah, and 446 images for Waru.

Image processing

After the fieldwork was conducted, the images were processed by using Agysoft Photoscan and Menci software (appendix 3). This step was conducted in the laboratory. The mosaicking images were printed in A0 papers with the scale map range between 1: 5,000 and 1: 10,000. The scale map 1:5,000 is for the residential area, while the scale map 1: 10,000 is for the other type of landscapes purposes.

3.3.3 Participatory mapping

The local communities consist of land parcel owners, and the neighbours gathered again to show their area and their land boundaries on the screen and the printed image. If the boundaries have been agreed by their neighbours, the land owners should sign the printed image. If they cannot identify their land parcels or the neighbours disagree with it, a ground checking will be carried out. Within this activity, it also includes interviews with the land owners. It is about their view comparing the UAV based mapping and the existing method, and the cost that they paid to measure their land parcels. The transcript interview is shown in appendix 4.

3.3.4 Output

The image which is agreed by land owners and neighbours, and existing data from land office are compared by delineating and computing the size of land parcels. In order to obtain the differential area and accuracy. Whilst, to gain the comparison of cost and duration, the experience on field and interviews with land owners and UAV's pilots are performed.

4. Results and Discussion

4.1 Results

In this sub-chapter, the results are given about the plan and preparation, image acquisition, participatory boundary mapping, comparison of cost, duration, and accuracy.

4.1.1 Plan and Preparation

Since the research involved several parties (e.g. communities, government institutions, and private sectors), the supporting documents consist of thesis proposals, cover letters, and official letters (in Bahasa) are prepared. An internal meeting between the land office of National Land Agency (Land Office of Bengkulu Tengah, Bogor and West Jakarta) and the private company were conducted regarding the datasets, instruments, and personal teams.

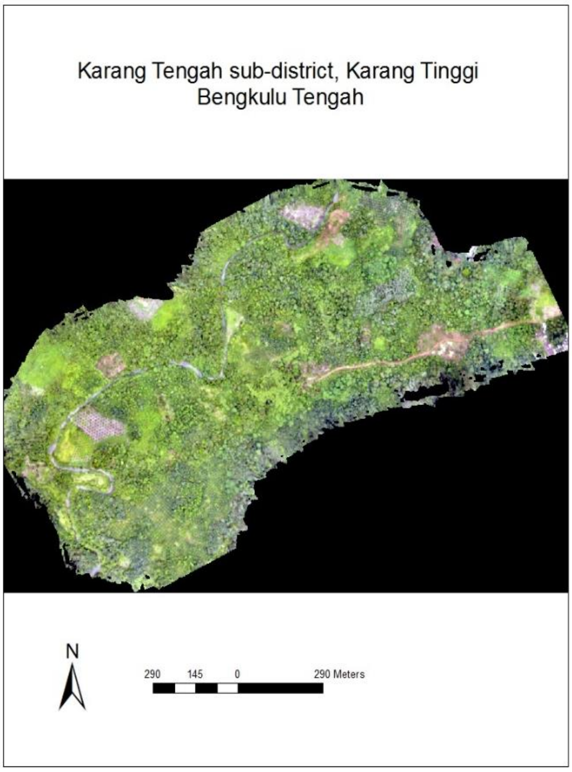
Further, a persuasive approach with the local communities was carried out. The aim of it was to ask for the permission to work in their properties.

In the first study area, Nakau and Karang Tengah, the range time of notification to discussion needs 2-4 days. It was caused by most of people were working on the plantation and it was hard to gather them in one place at the same days. In addition, in the second district, Waru, it only took 1 day. Both of local communities were very excited and accepted of UAV method (figure 10). Unfortunately, on the third place, Kembangan – West Jakarta, there was a rejection from the local authorities. They argue that measurement using UAV method will give the negative impacts on their privacy. Their anxieties were very reasonable due to land parcels are highly demanded, and there are many land dispute issues. Therefore, the research in the last area was not performed.

Figure 10. The meeting involved communities, government institutions, and private sectors.

4.1.2 Image acquisition

The fieldworks in the first study area has been completed in December 2016 and it was the rainy season. The ortho-image as the result of UAV method is shown in figure 11. Figure 11.a shows the topography of Karang Tengah which is hilly and covered by personal mixed and palm oil plantation. Moreover, Nakau has the flat terrain with small hills consist of residential areas fewer boundaries, a few of rice fields, personal mixed plantation, and palm oil plantation (figure 11.b).



(a). (b).

Figure 11. (a). ortho-image of Karang Tengah; (b). ortho-image of Nakau

The data acquisition using UAV method in second research area has been conducted in March 2017. Although it was drainy season, sometimes it was a heavy rain on the afternoon. The local community also suggested to carry out the fieldwork from 8.00 am to 12.00 pm. Waru is flat terrain consists of water fish ponds, residential area, and open field. The image processing on Waru is shown in figure 12.

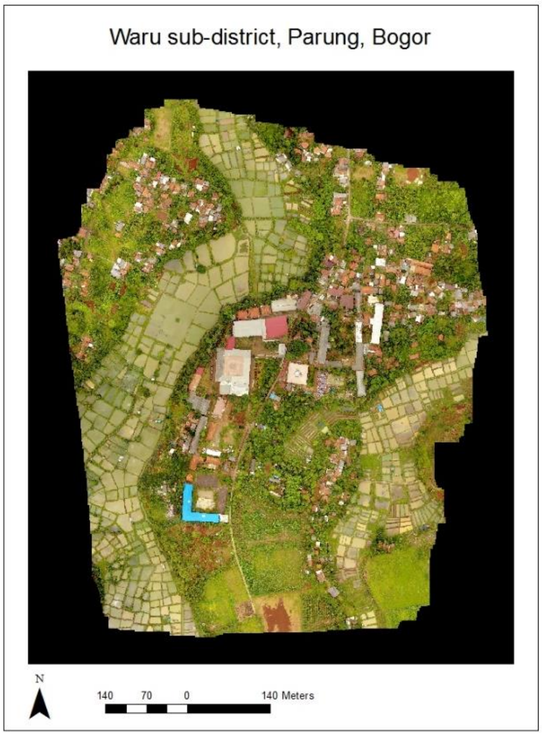


Figure 12. ortho-image of Waru

4.1.3 Participatory boundary mapping

After the image pre-processing was finished, the local communities in each sub-district gathered again in the village offices. These meetings aimed to test the participatory mapping could define their land parcel boundaries or not. In Nakau and Karang Tengah were conducted in 23 and 26 December 2016, while in Waru was performed on 30 of March 2017. Around 20 and 10 people came in the offices of Nakau and Karang Tengah respectively, where as 20 people came together in Waru (figure 13).

Most of the local people in Nakau who have residential parcels and rice fields could identify their land parcel boundaries. A few of them and the land owners of personal mixed and palm oil plantation could not define the boundaries. This condition also occurred in Karang Tengah, they could not shown the boundaries of their properties. On the other hand, the people in Waru could define their properties boundaries such as water fresh fish ponds, residential areas, open fields, and public facilities.

Figure 13. participatory boundary mapping meeting

According to the interview results in appendix 4, the local communities in Nakau and Waru could recognise their land parcels, unfortunately the people in Karang Tengah could not show their property boundaries. Although not all of them were able to point out their land parcels, the individuals in the study areas not objected when their properties measured by using UAV method. They state that UAV is a more sophisticated tool than the conventional one.

The local communities also asked about the duration of land cadastral registration using terrestrial, the cost of installing boundary markers, the size of the area, and the type of landscapes of their properties.

4.1.4 Cost

The comparison cost between the using of terrestrial method and UAV method is shown in table 5. The amount of cost value of terrestrial method is generated from the budget report of the national document of Indonesia about general fee standards (Appendix 5), while UAV method is derived from the interview with several UAV's pilots and field experience.

Table 5. The cost value between terrestrial and UAV measurements

No.	Routine Cost	Terrestrial Measurement (IDR)*	Terrestrial Measurement (EUR)*	UAV (IDR)	UAV (EUR)**
1	pilot/ engineer salaries	298,872	21.05	400,000	28.17
2	Cost of equipment (software, hardware)	600,000	42.25	533,333	37.56
3	Vehicles operation	600,000	42.25	500,000	35.21
4	Boundaries marker	600,000	42.25	0	-
	Total cost	2,098,872	147.81	1,433,333	100.94

*IDR: Indonesian Rupiah

**convert IDR to EURO based on Bank Indonesia

Due to the boundary markers are provided by land owners and the cost to build the markers has a different price in each area, the cost of boundary markers is the average price. As shown in table 5, UAV has lower cost than the terrestrial method. If UAV only took IDR 1,400,000 or around € 101 on one flight, the terrestrial need IDR 2,000,000 or €147 per parcel. Thus, the different cost value using terrestrial measurement and UAV based mapping is around IDR 665,000 or €46.

4.1.5 Duration

Table 6 shows the proportion of time spent to measured the land parcels using terrestrial and UAV method. The duration of land measurement using terrestrial method is generated from the interviews with local communities and the land officers. The duration of UAV method is derived from the interviews with the UAV's licensed pilots and based on the field experince. The duration activities on both of methods consist of plan and preparation, acquisition, processing, and output on research in Nakau, Karang Tengah, and Waru.

Table 6. Duration activities between terrestrial and UAV methods

No.	Activity	Nakau				Karang Tengah				Waru			
		Terrestrial methods		UAV methods		Terrestrial methods		UAV methods		Terrestrial methods		UAV methods	
		Duration (hour)	unit (parcel)	Duration (hour)	unit	Duration (hour)	unit (parcel)	Duration (hour)	unit	Duration (hour)	unit (parcel)	Duration (hour)	unit
1	plan and preparation	10	1	48	50 Ha	10	1	24	40 Ha	6	1	16	60 Ha
	Notification												
	administration												
	material preparation												
2	measurement/ image acquisition	5	1	1	37 parcels	3	1	1	3 parcels	2	1	4	46 parcels
3	processing	1.5	1	8	37 parcels	1.5	1	5	3 parcels	1	1	3	46 parcels
4	output generation	1	1	1	37 parcels	1	1	1	3 parcels	1	1	1	46 parcels
		17.5	1	58	37 parcels	15.5	1	31	3 parcels	10		23	46 parcels
	total (hours per parcel)	17.5		1.6		15.5		10.3		10		0.5	

As shown in table 6, land measurement in Nakau has the longest time. By using terrestrial method, it took 17.5 per parcel. Whilst, using UAV method, it took 58 hours for 37 parcels, or only need 1.5 hours to measured 1 land parcel. The long duration of UAV method also occur in Waru. It requires 23 hours to map 46 parcels, or it needs 10 hours to measure a parcel of land.

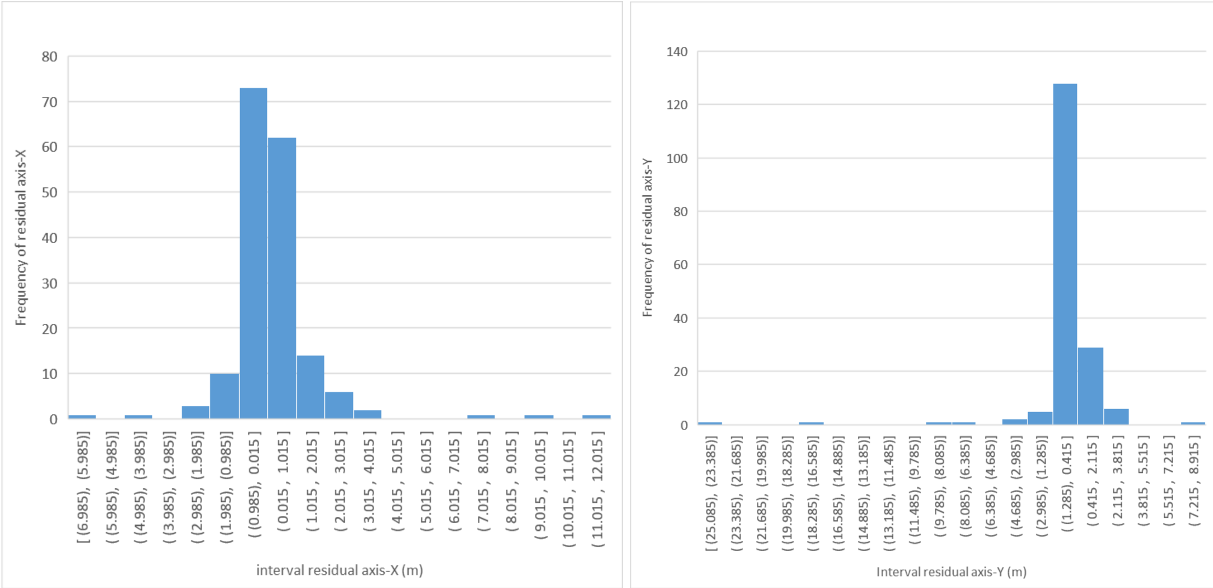
The time spent to measure land parcels using UAV method is affected by location of land parcels, the transportation access, topography, the size of the area, and what kind of terrestrial equipment that was used. Land parcels in Karang Tengah were located in high terrain; in the remote area; the size area is more than 1 Ha; the type of landscapes are personal mixed or palm oil plantation, and used vegetation as boundary markers; and used GPS geodetic/ Total Station to measure the land parcels. Thus, the land parcels in this area took a longer time, and it's hard to identify the boundaries. Nakau and Waru have a low to flat terrain; the transportation access is relatively easy; the size area is less than 1 Ha; the type of landscapes consist of the residential area, water fish ponds, and open fields which installed the concrete boundary markers or used the fence on around their properties; and use GNSS CORS to measure. Therefore, It did not take much time to measure their properties.

4.1.6 Accuracy

The data of difference accuracy and area are derived by over-laying the existing data and UAV image which is agreed by the land owners and their neighbours. The existing data are obtained from land office of Bengkulu Tengah (for Nakau and Karang Tengah), and land office of Bogor for study area in Waru district (see appendix 6). Whilst, UAV – participatory mapping data are derived from field collection which agreed by the local communities, it manually digitized, delineated, and exported to Ms Excel (see in compact disc).

Nakau – Bengkulu Tengah

There are 4 type of landscapes that are used as sampling data in Nakau: residential area, personal mixed plantation, field rice, and palm oil plantation. Because the residential area has a larger number of parcels than the others, 27 of sampling parcels are used. Followed by personal mixed plantation: 4 parcels. Field rice and palm oil are 3 parcels respectively. In order to define the coordinate accuracy, the histogram of deviation coordinates errors (figure 14) and difference area are made (figure 15).



Histogram ΔX (m) (b) Histogram ΔY (m)

Figure 14. The histogram of residual coordinate errors in Nakau

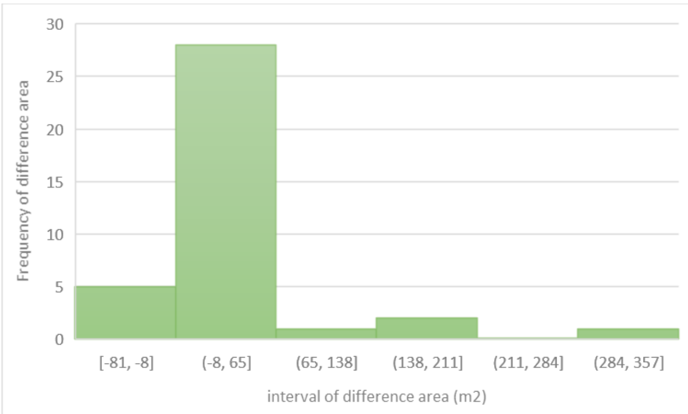


Figure 15. The histogram of difference area in Nakau

The residual of axis-X in Nakau is shown in figure 14.(a), axis-Y is shown in figure 14 (b). The range of residual axis-X is between -0.5 and 0.8 meter, while the range of residual of axis-Y is from -0.3 to 3 m. Approximately 70% of difference area in between -8 and 65 meters (figure 15). Further, the highest residual coordinate errors and difference area in each of type of landscapes are described in table 7.

Table 7. The highest residual coordinate errors and difference area in Nakau

Type of landscapes	Residual axis-X (m)	Residual axis-Y (m)	Difference area (m^2)
Palm oil plantation	11.11	25.09	338
Personal mixed plantation	4.45	1.63	162
Residential area	2.22	0.82	-81
Rice field	1.08	0.08	5

As shown in Table 6, the highest residual coordinate errors and difference area occur in palm oil plantation, whereas rice field is the lowest one. The greatest residual axis-X of palm oil plantation is

11.11 m (Figure 16 point 2), while residual axis-Y is 25.09 m (figure 16 point 3). The difference area in this parcel is 338 m^2. In addition, the residual axis-X and axis-Y in rice field are 1.08 and 0.08 m respectively (figure 17 point 1), whereas the different area is only 5 m^2.

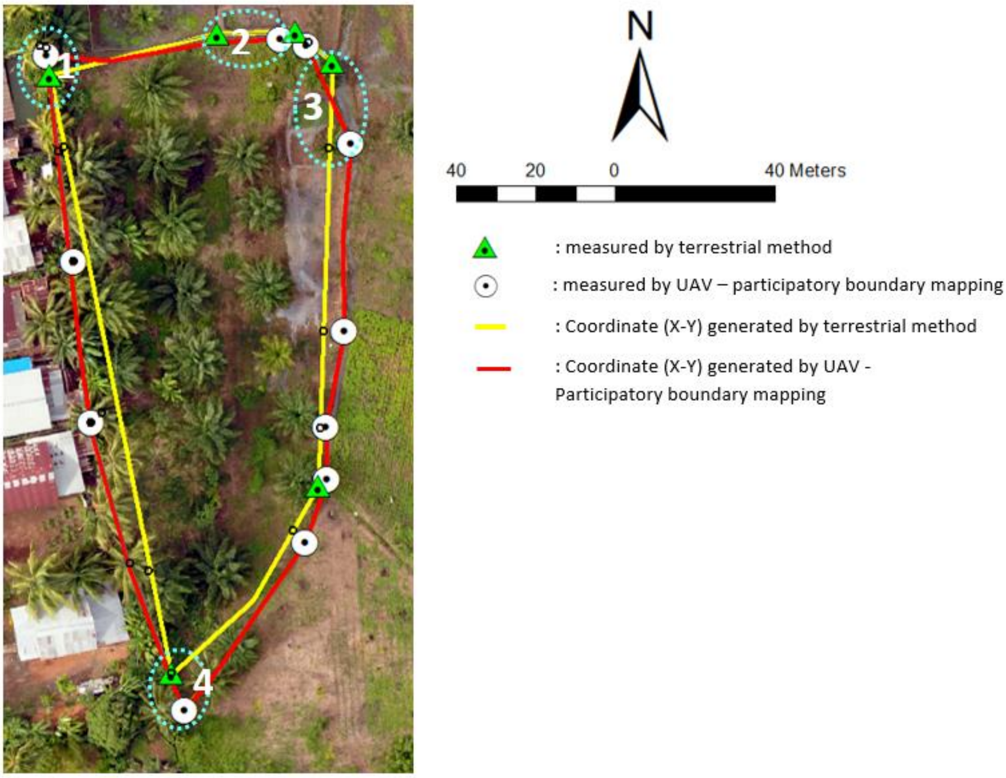


Figure 16. The highest residual coordinates errors and difference area in Nakau

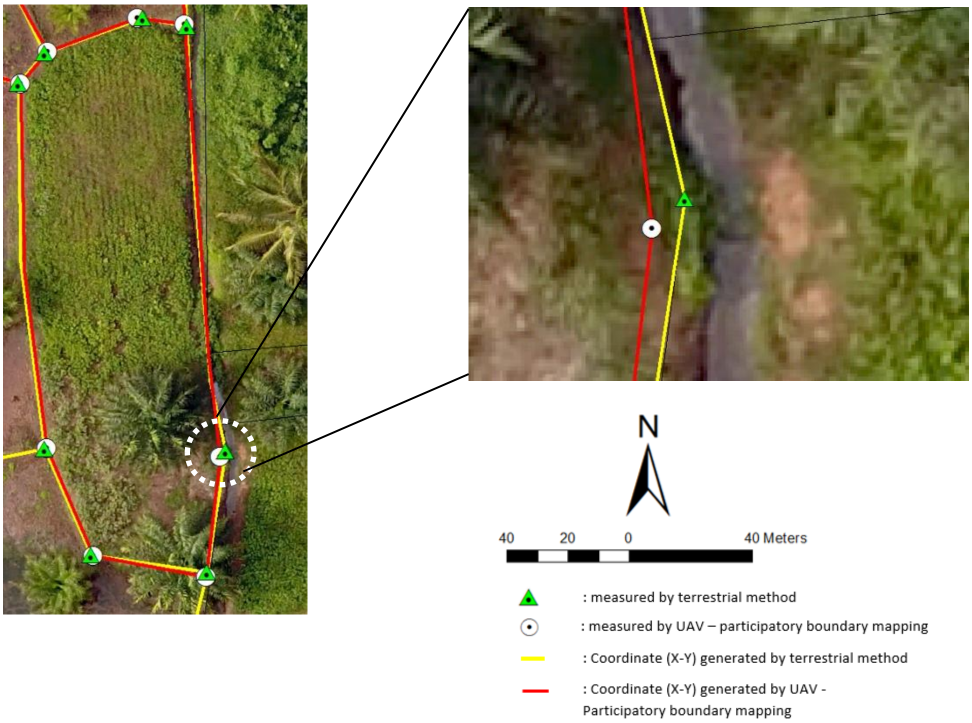
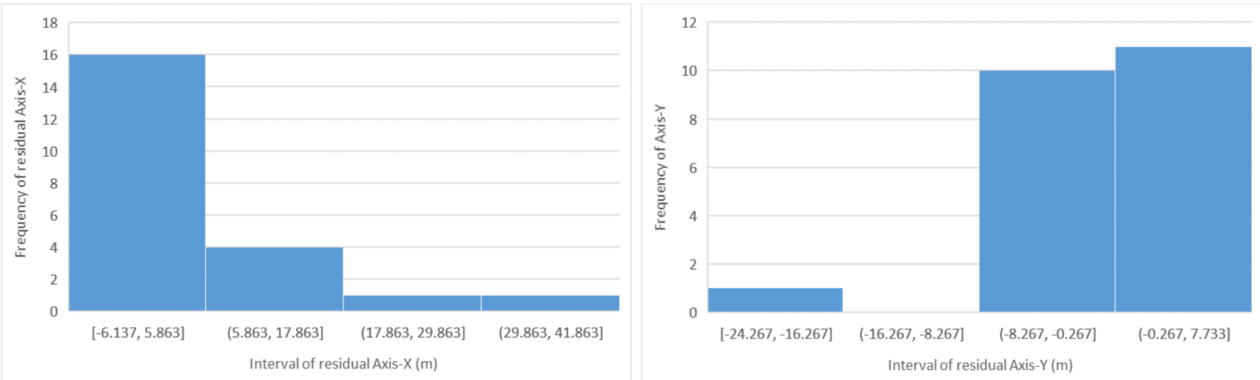


Figure 17. the lowest residual coordinate errors and difference area in Nakau

Karang Tengah – Bengkulu Tengah

The landscapes in Karang Tengah are fully with plantations: palm oil and personal mixed plantations. The access location through this area is very difficult (figure 18), therefore the sampling only took 1 land parcel for palm oil and 2 parcels for personal mixed plantation. The histogram of deviation coordinate errors is shown in figure 19, while the graphic of differential area is shown in figure 20.

Figure 18. field area in Karang Tengah



(a). Histogram ΔX (m)

(b). Histogram ΔY (m)

Figure 19. Histogram of residual coordinates in Karang Tengah

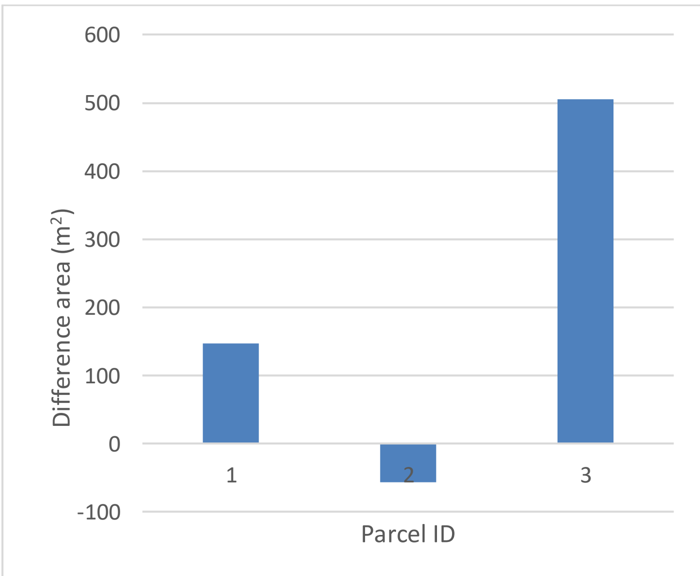


Figure 20. the graphic of difference area in Karang Tengah

As shown in figure 18 (a), mostly residual axis-X is in the range of -6.1375 m to 5.863 m, while the range for residual axis-Y in between -8.267 m and 7.733 m. Figure 19 shows the high value of difference area in both of type of landscapes, 500 m^2.

The highest coordinate deviation errors occurs in palm oil. With the residual axis-X is 33.86 m (figure 21, point 1), and residual axis-Y is -6.349 m (figure 21, point 2), whereas the different area is 505 m^2. In personal mixed plantation, the residual axis-X is 16.08 m, and residual axis-Y 24.26 m, while the difference area is -57 m^2.

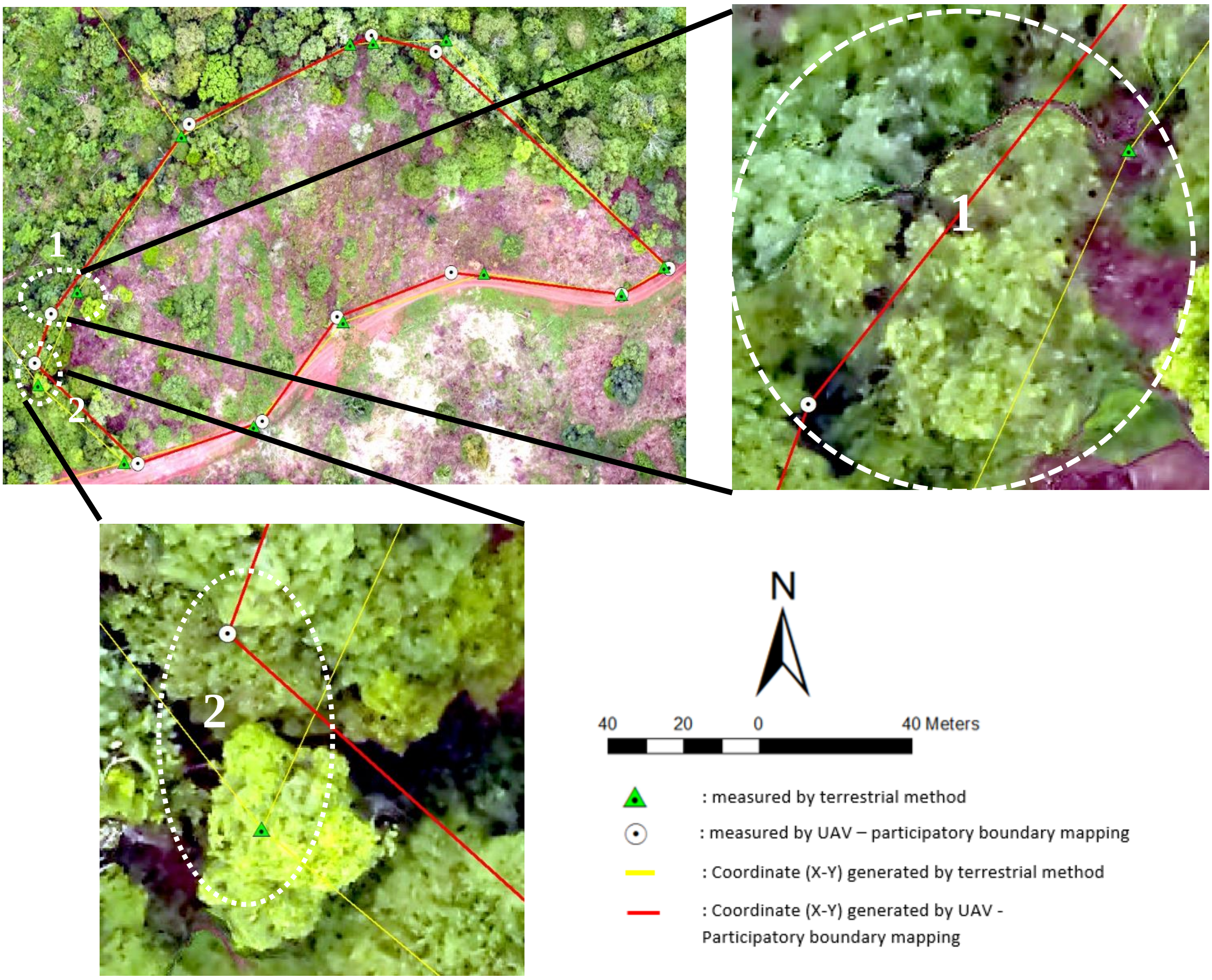
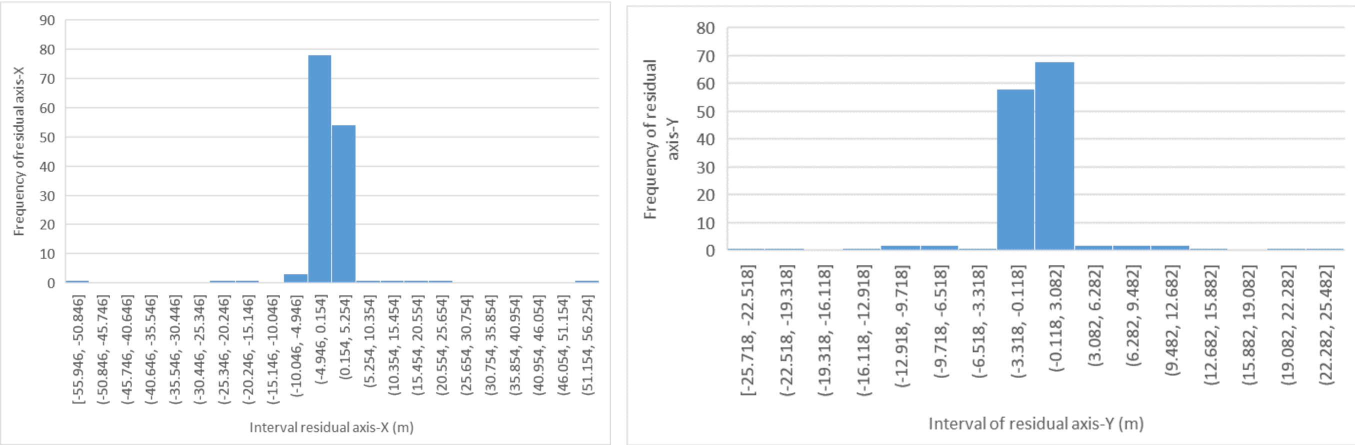


Figure 21. Residual coordinate errors and difference area in Nakau

Waru - Bogor

The type of landscapes in Waru are including residential area, public facilities, water fish ponds, and open fields. 31 sampling data were taken which consist of 16 land parcels of water fish ponds, 9 residential area, 5 open fields, and 1 public facility. Based on that, the histogram of residual axis-X, axis-Y (figure 22), and difference area are made (figure 23).

As shown in figure 22 (a), mainly the residual axis-X in between -0.671 m and 1.109 m, range the residual axis-Y is from -0.701 to 0.879 m, and the different area is around -30 to 16 m^2. Further the largest residual axis-X, axis-Y, and difference area in each of type of landscapes is described in table 7.



(a). Histogram ΔX (m) (b) Histogram ΔY (m)

Figure 22. Histogram of residual coordinate errors in Waru

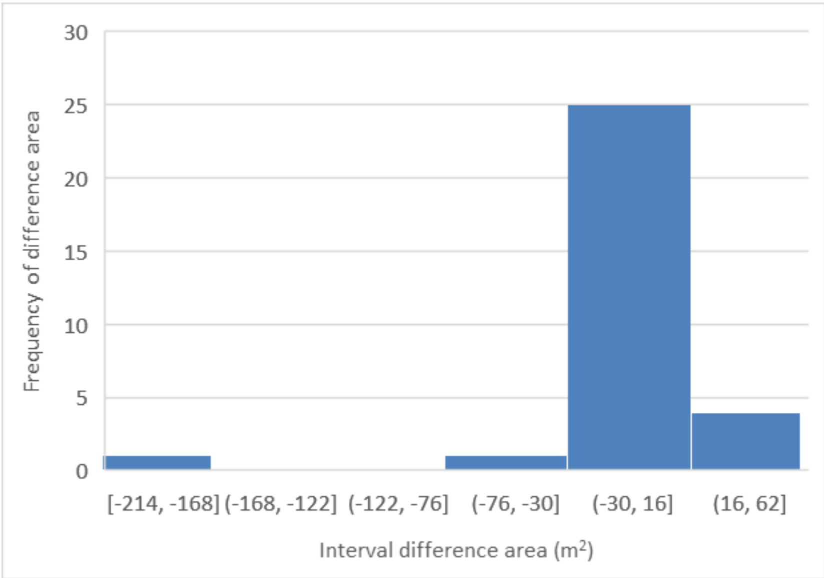
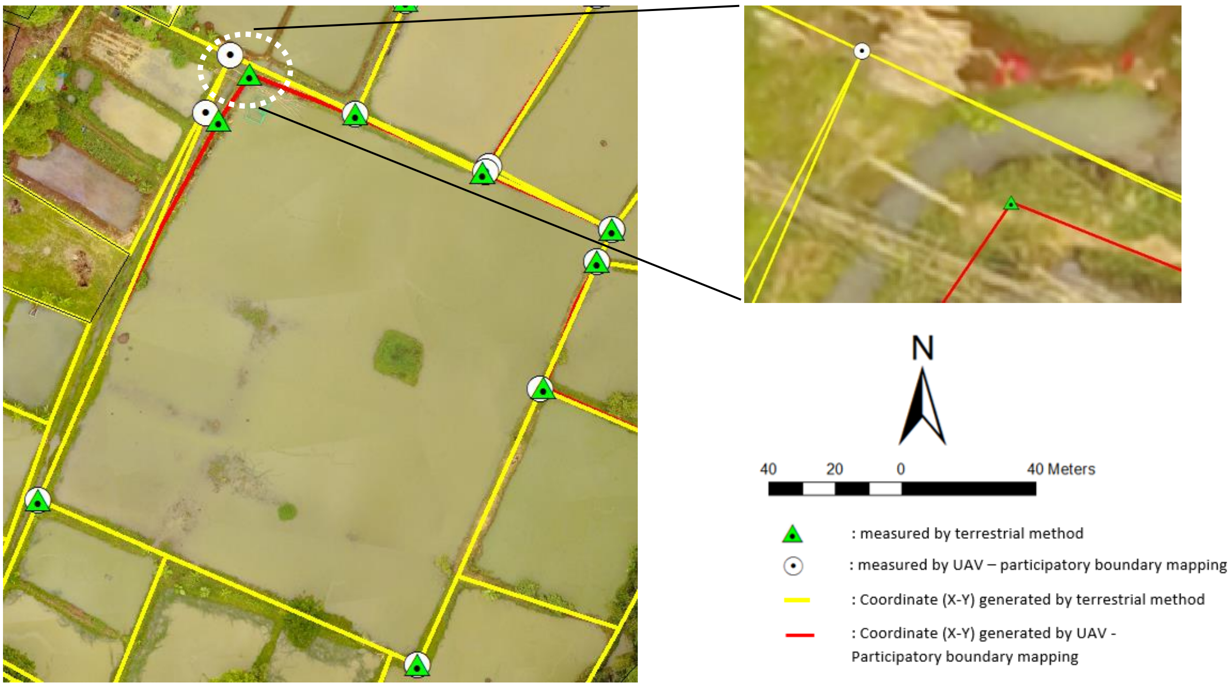


Figure 23. Histogram of difference area in Waru

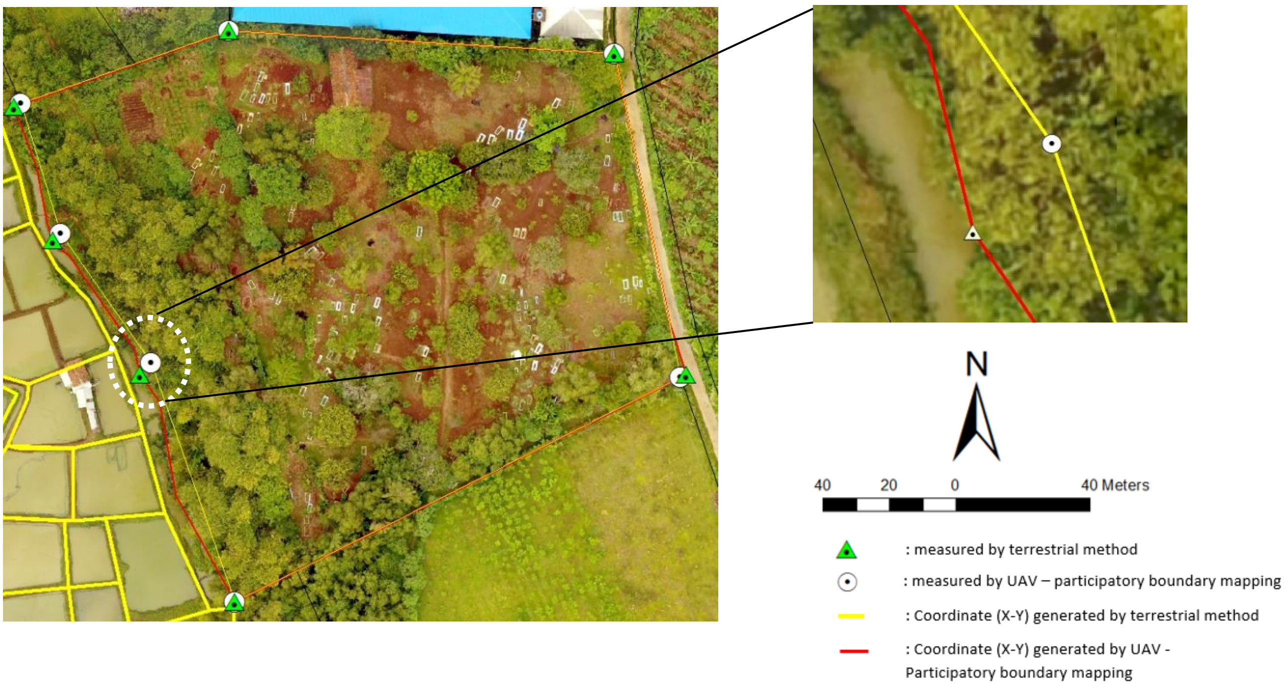
Table 8. the highest deviation coordinate errors and difference area in each of type of landscapes in Waru

Type of landscapes	Residual axis-X (m)	Residual axis-Y (m)	Difference area (m^2)
Public facility	-3.122	3.161	-214
Water fishpond	-5.122	1.783	-49
Resident area	-2.902	1.777	20
Open field	-4.567	-0.718	26

Based on table 8, water fishpond is the highest residual on axis-X (figure 24 (a)). Public facility has the highest residual axis-Y and the largest difference area (figure 24 (b)).



(a) the highest residual axis-X in Waru



(b). the highest residual axis-Y and the largest difference area in Waru

Figure 24. the highest deviation coordinate errors and difference area in Waru

Based on the Indonesian's cadastral standard that shown in Table 4, the deviation coordinate errors in Nakau, Karang Tengah, and Waru are too high and not acceptable for land cadastral registration purposes. The high value both of residual coordinates and difference area among in Nakau, Karang Tengah, and Waru are caused by the unclear boundary markers. Even though the parcels have not vegetation covered, the deviation both in coordinate and area are still high value. It is caused by there is no boundary markers, or use the vegetation as markers. When the vegetation boundary is disapeared, the parcel boundary cannot be identified.It can be concluded that UAV can be used for cadastral map registration only in landscapes which have a clear land cover of land parcels area. Whilst, in land covered with vegetation, the equipment cannot be used.

4.2 Discussion

4.2.1 General discussion

The implementation of photogrammetric as one of methods to measure land cadastral registration has been regulated in Minister Agrarian/ NLA regulation No. 3/ 1997. Since aerial photograph is most expensive technique, and its result is low resolution image, this method is only used for specific mapping purposes. Such as for mapping the forest and plantation area (Sumarto et al., 2008). Thus, terrestrial method is one option to measure the land parcels. The main problems using this method are topography and type of landscapes, where the land in Indonesia is mostly hilly and has dense vegetation.

Even though the residual coordinate errors generated from UAVs and existing data resulted is too high value and not acceptable for land cadastral registration purposes, UAVs are possible to measure the area with clear boundaries of land parcels. High deviation coordinate errors and difference area are derived from the type landscapes which the boundaries are covered with plantation or used vegetation as boundaries such as palm oil, personal mixed plantation have a low accuracy than landscapes with have clear boundaries (e.g. field rice, residential area with clear boundaries, and water fresh fish ponds). Time spent to measure the land using UAV method is longer than terrestrial method, but UAV method can mapped several land parcels in one project. UAV also low cost method than conventional one. It can be concluded that using UAV method is faster, more efficient, and inexpensive than terrestrial method.

As a new technique, participatory boundary mapping in UAV method is not entirely efficient. Since it is conducted after the land measurement, it takes time to gather the local communities in one place. Therefore, an effective communication is required. Even though the official letters which are signed by the head office of the land office, but it is not enough. Directly meeting and discussion with the local authorities is also needed. It because the Indonesian's people have stereotype that it is more honourable and polite if asking the permission in directly. Further, all parties involved should understand the approach by knowing their role and giving the explanation of land parcels to the local communities.

4.2.2 Reflection

Several researches in Indonesia agree that using UAV for mapping purposes is more effiecient, effective, has higher accuracy, and lower cost than the conventional one. Nevertheless, the research that using UAV for land surveying in Indonesia is very rarely. There is a research that is conducted by Ramadhani (2016) who combining participatory boundary mapping and UAV for surveying boundary mapping in small district (32 Ha) in West of Nusa Tenggara, Indonesia. She only took rice fields for her object. She conclude that UAV is compatible to cadastral purpose which the accuracy can improve to 3.004 cm. She also states that UAV is affordable which the cost is 70% cheaper than using terrestrial method (Ramadhani, 2016). Radjawali & Pye (2015) also conducted a research that use UAV for land mapping purposes is performed in West Kalimantan.

It also involves the community to identify their land properties. The aim for the research is only to prevent the land grabs and land disputes. But it did not mention and classify what type of landscapes that was studied (Radjawali & Pye, 2015). Another research that use UAV for land mapping purpose is carried out by Sadikin et al., (2014). They only concern on identification and inventory of state assets (Sadikin et al., 2014).

Reflected on these researches, the study about the UAV for land cadastral registration purposes which also represent the whole type of landscapes in Indonesia is performed. To achieve program which register all of land parcels in Indonesia on 2025, NLA has used satellite imagery with a high accuracy for land base map and to measure land cadastral. Unfortunately, there are still many of areas which are not covered. Therefore, the results of this research also as input to NLA to use UAV as a method or alternative method for land surveying purpose.

On developed countries, the uses of UAV for land surveying and mapping is very restricted and only use for the government purposes. In Netherlands, only the national land registration service and mapping agency can use UAV for juridical verification of cadastral borders of real estate (Rijsdijk et al., 2013). In Alaska State-USA, only The international Assosiation of Assessing Officers (IAAO) which can use UAV for tax assessment and audit purposes (Cunningham et al., 2011). Represented from developed countries, NLA has to formulate a special policy of UAVs. It regulates the restrict uses of UAVs for surveying and mapping purposes.

5 Conclusion and recommendation

5.2 Conclusion

In this sub-chapter an overview of conclusions is provided. It also addresses the results of research questions which were formulated at the beginning of this research. The conclusions are presented below:

Q1: How many parcels can be mapped per day?

By applying UAV, there are 273 land parcels in Nakau and Karang Tengah, and 843 land parcels in Waru that can be mapped per 37.3 hours. The difference number of land parcels generated from two study areas affected by the topography (type of landscapes), weather, location and access to the location, the equipment that used to GCP's measure, the output accuracy (e.g. GSD, height flight, side lap), the kind of UAV, etc.

Q1.2: How long does it take for different type of landscapes?

The landscapes which the boundaries are covered with plantation or used vegetation as boundary markers such as palm oil and personal mixed plantation have longer time to be mapped than landscapes with have clear boundaries (e.g. field rice, residential area with clear boundaries, and water fresh fish ponds).

The sampling data (3 land parcels) in Karang Tengah which include personal mixed and palm oil plantation, has the longer duration, 31 hours. To measure each of them, it took 10,3 hours. In Nakau which have 37 parcels consist of residential area, rice fields, palm oil plantation, and personal mixed plantation, it took 58 hours. Each of land parcels needs around 1.5 hours. Whilst, it is only took 23 hours to measure 46 land parcels or only 0.5 hours per parcel in Waru, that include residential area, water fresh fish ponds, open fields, and public facilities.

Q2: How much does it cost in time and money to map a parcel compared to GNSS rover and GPS geodetic

Generally, UAV is more efficient and cheaper than terrestrial methods. Although it needs an extra time to map 30-50 Ha, UAV has lower cost rather than measuring GNSS rover or GPS geodetic. If UAV only needs IDR 1,400,000 or around € 101 for one flight, the conventional method need IDR 2,000,000 or €147 per parcel.

Q3: What is the accuracy of the UAVs base map?

The low accuracy in several types of landscapes between the study areas is caused by the unclear boundary markers, either the markers are covered by vegetation or the community used plantation as boundaries markers. It can be concluded that UAV can be used for cadastral map registration only in landscapes which have a clear land cover of land parcels area. While, in land covered with vegetation, the equipment cannot be used.

Q4: What are the issues encountered when combining UAV surveying in combination with participatory mapping?

In UAV method, the participatory mapping performs after the land gets measured. As a new measurement method, a persuasive approach must be conducted. A letter notification and pre-meeting between local authorities should be carried out to give an overview and ask for the permission. Then, the land measurement and participatory boundary mapping are conducted. The long procedures make participatory mapping in UAV method is not efficient yet.

5.3 Recommendation

Based on the research, below are several recommendations:

1. UAV method is promising tool that can be used to support land measurement. Unfortunately, this method is not able to map the type of landscapes where the boundaries are covered with vegetation. Therefore, it requires the research to investigate and to determine where the UAV can be a useful tool.

2. UAV method has an acceptable accuracy in residential area, water fresh fish ponds, and the other landscapes which have clear land parcel boundaries. The other issues related to this method are the limited equipment and human resources. Thus, good communication and cooperation between the private companies and the government are required.

3. Further, to protect the privacy and properties, the government should enact a regulation about the use of UAV for mapping and measuring purposes.

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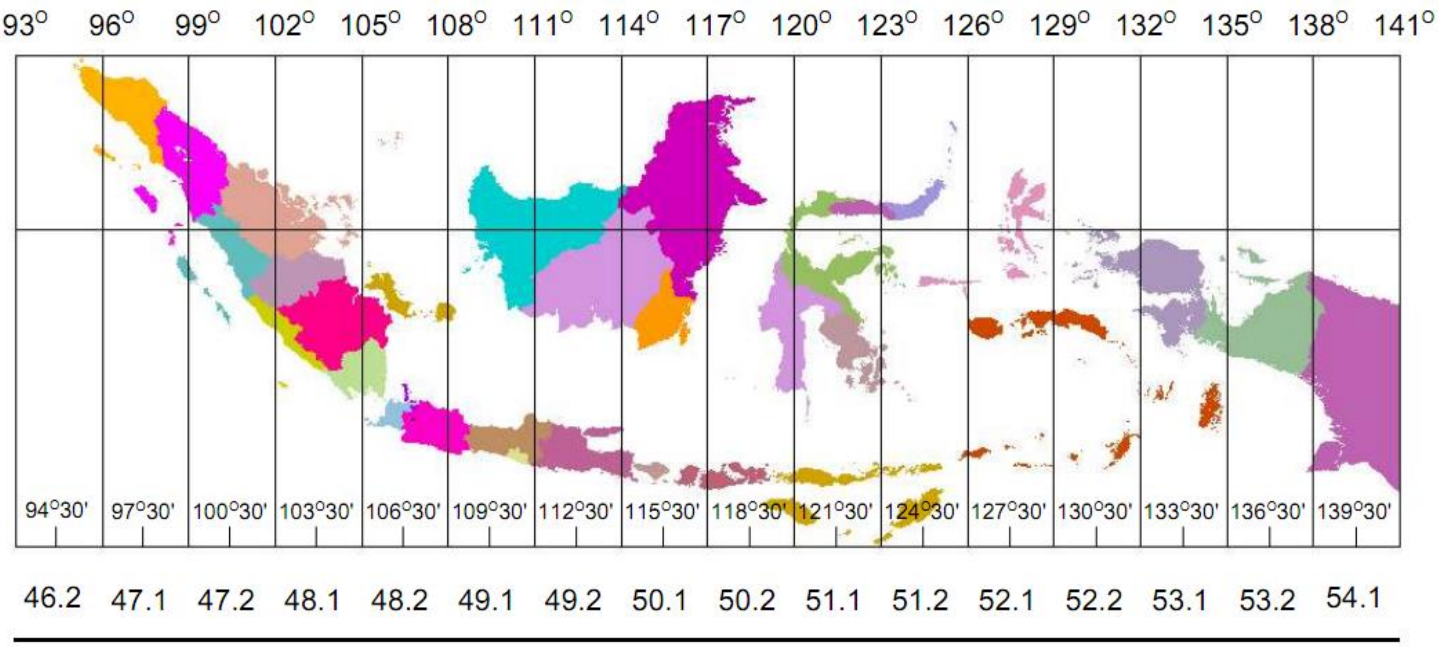
Appendix

Appendix 1.

Zoning TM 3°



Description : Coordinate reference system used in Indonesia is Universal Transverse Mercator (UTM). TM 3° derived the dividing UTM into two parts.

Datum : WGS 1984, a = 6387137, f= 1/298.25722357

Projection : Transverse Mercator

Parameter : False Easting = 200,000, False Northing = 15,000,000, Scale Factor = 0.9999. Latitude origin: 0o.

Linear unit : Meter

Appendix 2.

The Unit Price for Special Fee (HSBKu)

No.	Province	HSBKn Agriculture (IDR)	HSBKn Agriculture (EUR)*	HSBKn Non Agriculture (IDR)	HSBKn Non Agriculture (EUR)*
1	Aceh	50,000	3.55	100,000	7.09
2	North Sumatera	50,000	3.55	100,000	7.09
3	Bengkulu	30,000	2.13	60,000	4.26
4	Jambi	50,000	3.55	100,000	7.09
5	Riau	60,000	4.26	120,000	8.51
6	West Sumatera	50,000	3.55	100,000	7.09
7	South Sumatera	50,000	3.55	100,000	7.09
8	Lampung	40,000	2.84	80,000	5.67
9	Bangka Belitung Island	50,000	3.55	100,000	7.09
10	Riau Island	50,000	3.55	100,000	7.09
11	Banten	50,000	3.55	100,000	7.09
12	DKI Jakarta	60,000	4.26	120,000	8.51
13	West Java	50,000	3.55	100,000	7.09
14	Middle Java	40,000	2.84	80,000	5.67
15	Di Yogyakarta	40,000	2.84	80,000	5.67
16	East Java	50,000	3.55	100,000	7.09
17	Bali	50,000	3.55	100,000	7.09
18	West Nusa Tenggara	30,000	2.13	60,000	4.26
19	East Nusa Tenggara	20,000	1.42	40,000	2.84
20	West Kalimantan	40,000	2.84	80,000	5.67
21	South Kalimantan	50,000	3.55	100,000	7.09
22	Middle Kalimantan	50,000	3.55	100,000	7.09
23	East Kalimantan	60,000	4.26	120,000	8.51
24	Gorontolo	30,000	2.13	60,000	4.26
25	South Sulawesi	40,000	2.84	80,000	5.67
26	South-East Sulawesi	40,000	2.84	80,000	5.67
27	Middle Sulawesi	40,000	2.84	80,000	5.67
28	North Sulawesi	50,000	3.55	100,000	7.09
29	West Sulawesi	30,000	2.13	60,000	4.26
30	Maluku	20,000	1.42	40,000	2.84
31	West Maluku	20,000	1.42	40,000	2.84
32	West Papua	50,000	3.55	100,000	7.09
33	Papua	50,000	3.55	100,000	7.09

*convert IDR to EURO based on Bank Indonesia (http://www.bi.go.id/en/moneter/kalkulatorkurs/Default.aspx, accessed on 2 April 2017.

Appendix 3.

a. Quality report in Nakau, Talang Empat, Bengkulu Tengah using Agisoft Photoscan

Processing Report
20 December 2016

Survey Data

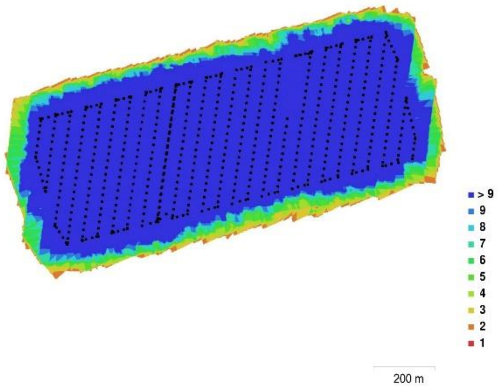


Fig. 1. Camera locations and image overlap.

Number of images:	652	Camera stations:	651
Flying altitude:	110 m	Tie points:	205,350
Ground resolution:	3.9 cm/pix	Projections:	669,985
Coverage area:	0.834 km²	Reprojection error:	3.08 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
FC330 (3.61mm)	4000 x 3000	3.61 mm	1.56 x 1.56 μm	No

Table 1. Cameras.

Camera Calibration

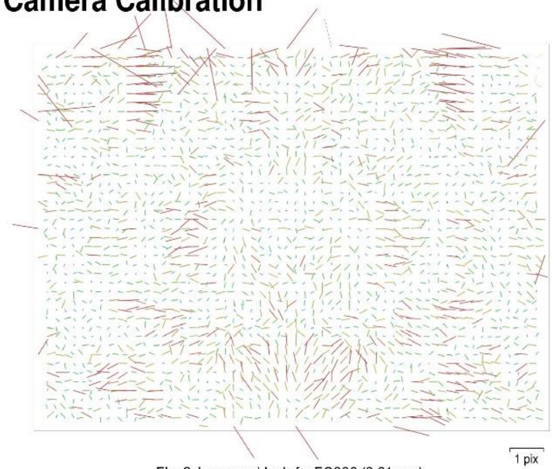


Fig. 2. Image residuals for FC330 (3.61 mm).

FC330 (3.61 mm)
652 images

Resolution	Focal Length	Pixel Size	Precalibrated
4000 x3000	**3.61 mm**	**1.56 x 1.56 μm**	**No**

Type:	Frame	F:	2311.25
Cx:	11.3605	B1:	-5.51771
Cy:	-18.7655	B2:	-1.34096
K1:	0.000234713	P1:	0.000218552
K2:	-0.00294785	P2:	-0.000206204
K3:	0	P3:	0
K4:	0	P4:	0

Camera Locations

Fig. 3. Camera locations and error estimates.
Z error is represented by ellipse color. X,Yerrors are represented by ellipse shape.
Estimated camera locations are marked with a black dot.

X error (m)	Yerror(m)	Zerror (m)	XY error (m)	Total error (m)
0.576588	1.59565	1.12615	1.69663	2.03637

Table 2. Average camera location error.

Digital Elevation Model

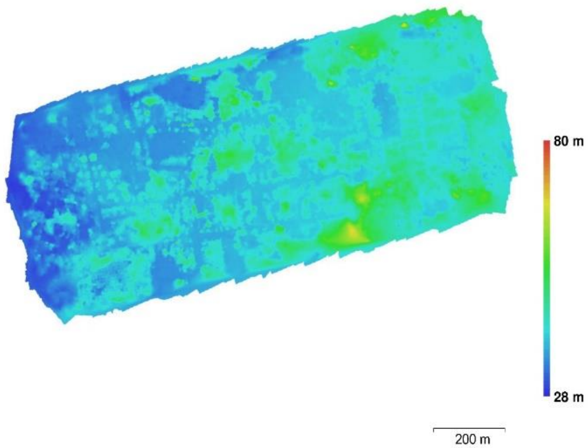


Fig. 4. Reconstructed digital elevation model.

Resolution:	1.76 m/pix
Point density:	0.324 points/m²

Processing Parameters

General	
Cameras	652
Aligned cameras	651
Coordinate system	TM3_Z48.1S / UTMzone 48S(EPSG::327481)
Point Cloud	
Points	205,350 of 232,469
RMS reprojection error	0.179177 (3.07988 pix)
Maxreprojection error	0.545805 (46.862 pix)
Mean keypoint size	15.7442 pix
Effective overlap	3.70745
Alignment parameters	
Accuracy	Low
Pair preselection	Reference
Keypoint limit	40,000
Tie point limit	4,000
Constrain features bymask	No
Adaptive camera model fitting	Yes
Matching time	12 minutes 8 seconds
Alignment time	6 minutes 45 seconds
Model	
Faces	84,759
Vertices	42,948
Reconstruction parameters	
Surface type	Height field
Source data	Sparse
Interpolation	Enabled
Geometrytype	Point cloud
Face count	90,000
Processing time	5 seconds
Orthomosaic	
Size	30,204 x18,736
Coordinate system	TM3_Z48.1S / UTMzone 48S(EPSG::327481)
Channels	3, uint8
Blending mode	Mosaic
Reconstruction parameters	
Surface	Mesh
Enable color correction	No
Processing time	11 minutes 23 seconds
Software	
Version	1.2.6 build 2834
Platform	Windows 64 bit

b. Quality report in Karang Tengah, Karang Tinggi, Bengkulu Tengah using Agysoft Photoscan

Survey Data

Fig. 1. Camera locations and image overlap.

Number of images:	1,807	Camera stations:	1,788
Flying altitude:	1.22 m	Tie points:	1,162,005
Ground resolution:	0.521 mm/pix	Projections:	3,885,713
Coverage area:	0 m²	Reprojection error:	1.45 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
FC330 (3.61 mm)	4000 x 3000	3.61 mm	1.56 x 1.56 μm	No

Table 1. Cameras.

Camera Calibration

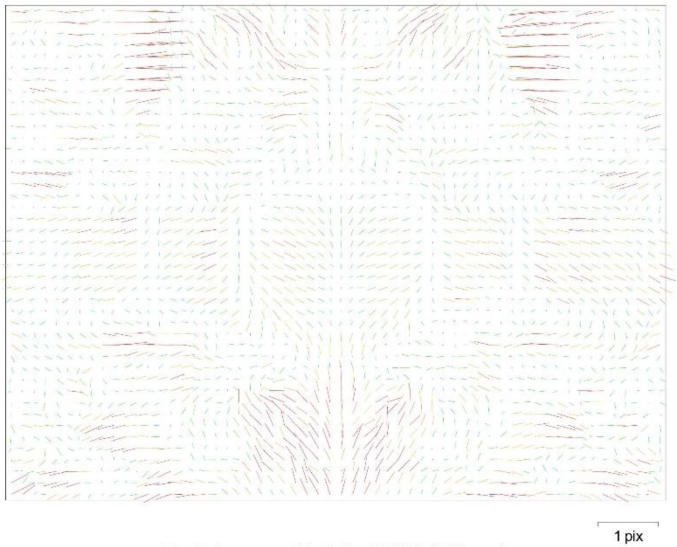


Fig. 2. Image residuals for FC330 (3.61 mm).

FC330 (3.61 mm)
1807 images

Resolution	Focal Length	Pixel Size	Precalibrated
4000 x 3000	**3.61 mm**	**1.56 x 1.56 μm**	**No**

Type:	Frame	F:	2344.34
Cx:	11.5073	B1:	-5.25144
Cy:	-25.0391	B2:	-0.0299038
K1:	0.0117375	P1:	5.70282e-05
K2:	-0.0393033	P2:	-0.000186702
K3:	0.0442279	P3:	0
K4:	-0.0184299	P4:	0

Camera Locations

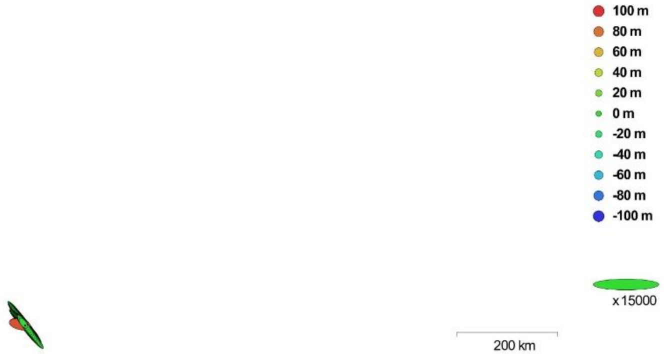


Fig. 3. Camera locations and error estimates.
Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.
Estimated camera locations are marked with a black dot.

X error (m)	Y error (m)	Z error (m)	XY error (m)	Total error (m)
1.08016	1.34973	8.84795	1.72874	9.01525

Table 2. Average camera location error.

Ground Control Points

Fig. 4. GCP locations.

Count	X error (km)	Y error (km)	Z error (km)	XY error (km)	Total (km)	Image (pix)
1	1.26948	5.11188	12.2285	5.26715	13.3146	0.000

Table 3. Control points RMSE.

Label	X error (km)	Y error (km)	Z error (km)	Total (km)	Image (pix)
base gcp1					(0)
detail 1	1.26948	-5.11188	-12.2285	13.3146	0.000 (1)
detail 2					(0)
detail 3					(0)
gcp 2					(0)
gcp 3					(0)
gcp 4					(0)
Total	**1.26948**	**5.11188**	**12.2285**	**13.3146**	**0.000**

Table 4. Control points.

Processing Parameters

General	
Cameras	1807
Aligned cameras	1788
Markers	7
Coordinate system	TM3_Z48.1S / UTM zone 48S (EPSG::327481)
Point Cloud	
Points	1,162,005 of 1,465,534
RMS reprojection error	0.22233 (1.45411 pix)
Max reprojection error	0.975989 (54.3496 pix)
Mean key point size	5.22473 pix
Effective overlap	4.60959
Alignment parameters	
Accuracy	High
Pair preselection	Reference
Key point limit	40,000
Tie point limit	4,000
Constrain features by mask	No
Adaptive camera model fitting	Yes
Matching time	3 hours 35 minutes
Alignment time	4 seconds
Orthomosaic	
Size	39,954 x 26,749
Coordinate system	TM3_Z48.1S / UTM zone 48S (EPSG::327481)
Channels	3, uint8
Blending mode	Mosaic
Reconstruction parameters	
Surface	Mesh
Enable color correction	No
Processing time	2 hours 34 minutes
Software	
Version	1.2.6 build 2834
Platform	Windows 64 bit

c. Quality report in Waru, Parung, Bogor using Merci

Report of the project Nurul Iman

Working Area

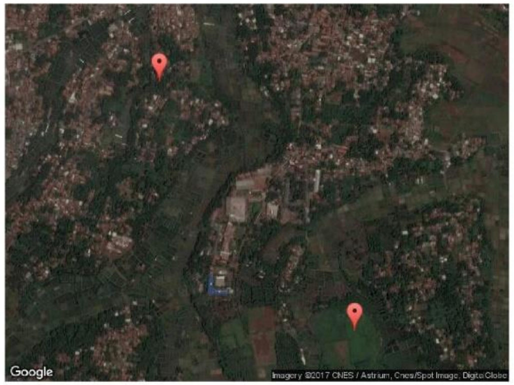


Figure 1: Working Area from Google Map

Summary

Project name:		Nurul Iman
Number of images:		448
Number of bundled images:		446
Area Covered:		0.608 Km^2
Average GSD:		0.049 m
Coordinate System	Projection:	UTM
	Datum:	WGS84
	Zone:	48 S

Images position and total features per image

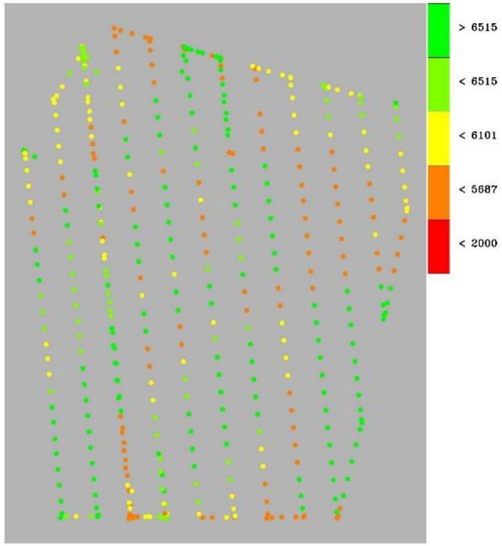


Figure 2: Images position and total features

Different colors are proportional to the number of potentially features in each image.
The features are particular object or shape that can be matched in the different pictures to link them.
The total number of potentially feature is represented in the legend.

No. of Features Max:	8171
No. of Features Min:	4859
Average Features:	6279

Matched Features

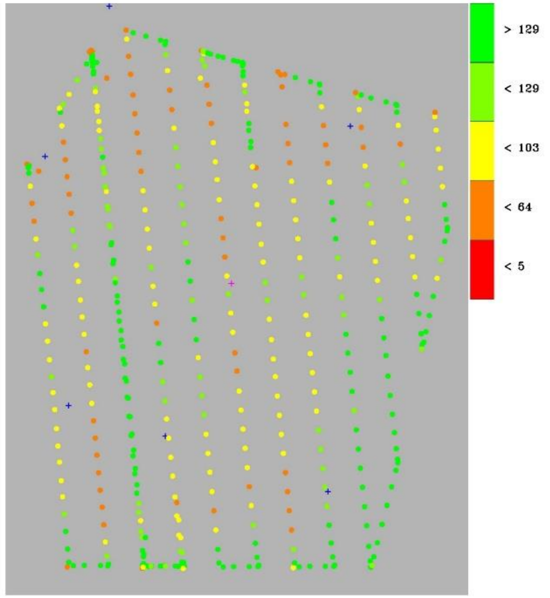


Figure 3: Matched features

Different colors are proportional to the number of matched features between images.
Each feature seen by at least 2 images can be matched between these 2 images.
The number of matched feature for each image is represented in the legend.
Blue cross represents verified GCPs. Purple cross represents unverified GCPs

No. of Matched Features Max:	397
No. of Matched Feature Min:	11
Average Matched Features:	129

Images Overlap

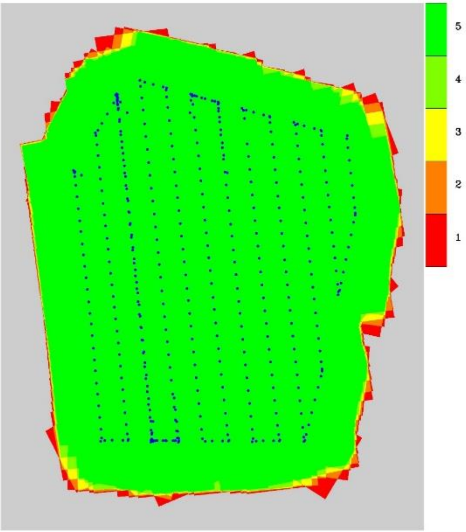


Figure 4: Image Overlap Graph

Overlap is the area that different pictures share. Good overlap means better connections.
In red areas overlap may be not sufficient, in green areas overlap is good, as reported in legend.

APS 8.1.0.0 Report

Connections Graph

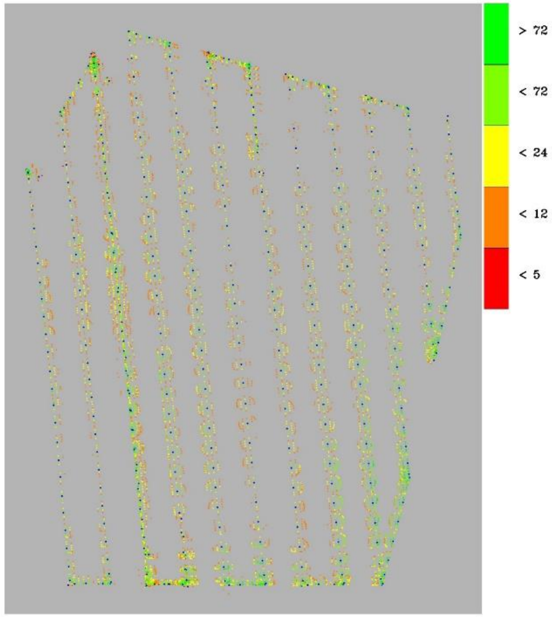


Figure 5: Connections Graph

Blue points represents the position of the pictures, the points around it represents the quality of the connection wit
other pictures and their relative position: the closer a point is to the blue center, the closer is the image it refer
The color represents the number of common points, as reported in the legend.
If a blue point is sorrounded mostly by green points means good connections, otherwise a lot -
of red points means bad connections, and more images or manual tie points could be required.

No. of Max Common Points:	362
No. of Min Common Points:	1
Average Common Points:	17

APS 8.1.0.0 Report

Connections Matrix

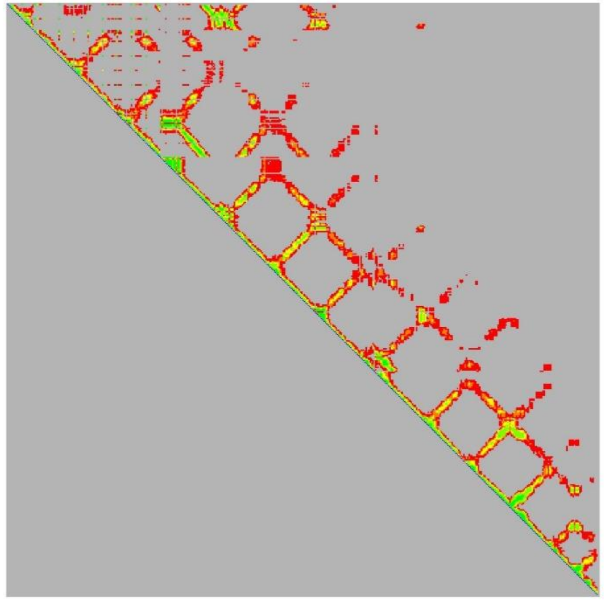


Figure 7: Connections Matrix

Connections Matrix is a matrix built considering the presence of connections between images and the strength of these connections.
Is a symmetric matrix, this is the reason why half of the image is empty.
To read it we have to consider that each square in the diagonal of the matrix (blue squares) represents a picture. Considering for example the first element in the diagonal in the first row, by moving through the same line we can see squares or empty spaces: a square means that the picture in the diagonal has connections with that image (the color indicates the number of elements in common), an empty space means no connections between these two images.
By clicking on the image is it possible to open the svg detailed version.

Connections Histogram

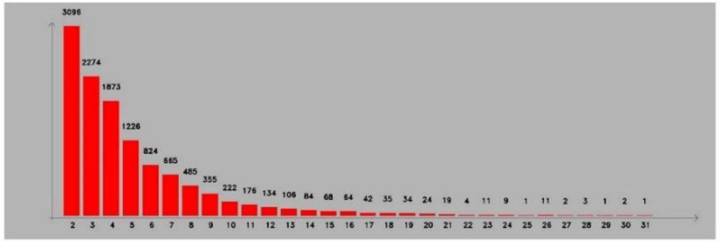


Figure 8: Connections Histrogram

Histrogram shows how the number of features is shared by images.
In Y is reported the number of features that are shared by images, in X is reported the number of images that are seeing those points.
For example there are 3096 features that are seen by only 2 images,
and only 1 feature is seen by 31 images.
By clicking on the image is it possible to open the svg detailed version.

Ground Control Points

Name	Verified	X err [m]	Y err [m]	Z err [m]	X err [pix]	Y err [pix]	Z err [pix]
1	✔	-0.013978	0.040740	-0.043044	0.2862	0.8342	0.8814
2	✔	0.005415	0.011474	0.012991	0.1109	0.2350	0.2660
3	✔	-0.019583	0.009944	-0.003902	0.4010	0.2036	0.0799
4	✔	-0.018383	-0.008458	-0.009970	0.3764	0.1732	0.2042
5	✔	0.006119	-0.017267	0.005070	0.1253	0.3536	0.1038
6	✘						
7	✔	0.004819	0.005144	0.003317	0.0987	0.1053	0.0679

Mean[m]	-0.005932	0.006930	-0.005923	0.0631	0.1469	0.0324
sigma[m]	0.004389	0.000729	0.003772	0.0427	0.0402	0.0301
RMS[m]	0.012954	0.019521	0.019030	0.2652	0.3997	0.3897

Appendix 4.

Interview transcription:

a. In Nakau

No.	Questions	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6
1.	Can you recognize your properties?	Yes	Yes	Yes	Yes	Yes	Yes
2.	How large the land parcels do you have?	300 m^2	700 m^2	1 Ha	800 m^2	500 m^2	500 m^2
3.	What the type landscapes do you have?	Resident	Rice fields	Personal plantation	Personal plantation	Resident	resident
4.	Did your parcel has registered?	Yes	Yes	Yes	Yes	No	yes
5.	How much money to make boundary markers?	Rp 400,000	Rp 400,000	Rp 400,000	Rp 400,000	-	Rp 400,000
6.	How long your property measured by terrestrial method include installed the markers?	0.5 hour	1 hour	1 hour	1.5 hours	1 hour	1 hour
7.	Do you objected if your properties measure again with UAV method?	No	No	No	No	No	No
8.	Your opinion about the UAV method?	Good	Good	Sophisticated	Good	Good	Good

b. In Karang Tengah

No.	Questions	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4
1.	Can you recognize your properties?	No	No	No	No
2.	How large the land parcels do you have?	1.5 Ha	1 Ha	1 Ha	1.2 Ha
3.	What the type landscapes do you have?	Palm oil plantation	Personal mixed plantation	Palm oil plantation	Palm oil plantation
4.	Did your parcel has registered?	Yes	Yes	Yes	Yes
5.	How much money to make boundary markers?	Boundary markers using vegetation	Boundary markers using vegetation	Boundary markers using vegetation	Boundary markers using vegetation
6.	How long your property measured by terrestrial method include installed the markers?	2.5 hours	2 hours	2 hours	2 hours
7.	Do you objected if your properties measure again with UAV method?	No	No	No	No
8.	Your opinion about the UAV method?	Good	Good	Good	Good

c. In Waru

No.	Questions	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6	Interviewee 7
1.	Can you recognize your properties?	Yes	Yes	Yes	Yes	Yes	yes	yes
2.	How large the land parcels do you have?	200 m^2	300 m^2	500 m^2	600 m^2	200 m^2	250 m^2	400 m^2
3.	What the type landscapes do you have?	Resident	Resident	Fishpond water	Fishpond water	Resident	resident	Fishpond water
4.	Did your parcel has registered?	Yes	Yes	Yes	Yes	No	yes	yes
5.	How much money to make boundary markers?	Rp 800,000	Rp 800,000	Rp 800,000	Rp 800,000	-	Rp 800,000	Rp 800,000
6.	How long your property measured by terrestrial method include installed the markers?	0.5 hour	0.5 hour	0.5 hour	1 hour	0.5 hour	0.5 hour	1 hour
7.	Do you objected if your properties measure again with UAV method?	No	No	No	No	No	No	No
8.	Your opinion about the UAV method?	Good	Good	Sophisticated	Sophisticated	Good	Sophisticated	Sophisticated

Appendix 5.

The budget report of the national document of Indonesia about general fee standards in bahasa

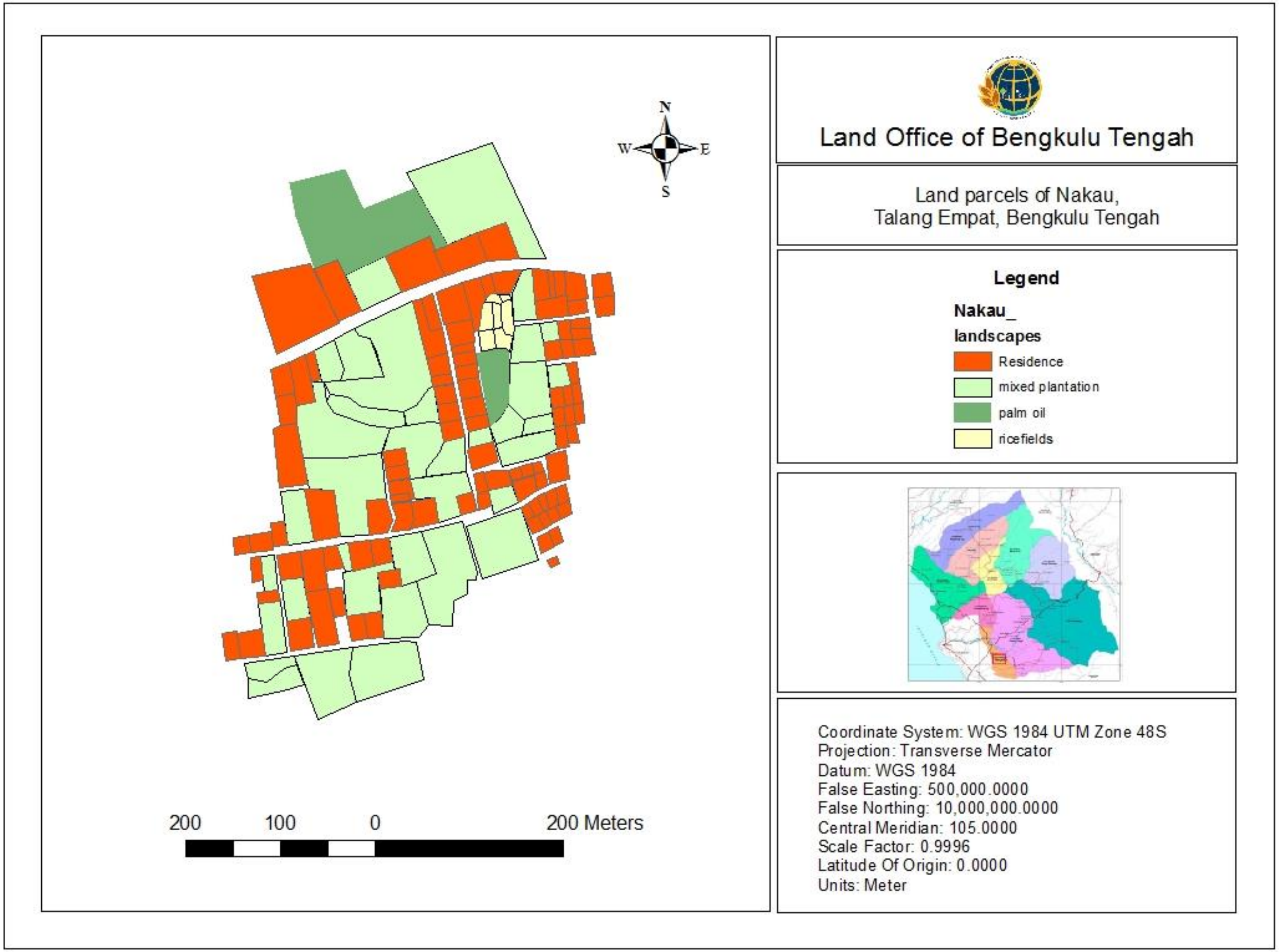
RINCIAN KERTAS KERJA SATKER T.A 2016

KEMEN/ LEMB : (056) KEMENTERIAN AGRARIA DAN TATA RUANG/ BPN
UNIT ORG : (01) Sekretariat Jenderal
UNIT KERJA : (689430) KANTOR PERTANAHAN KABUPATEN BENGKULU TENGAH
ALOKASI : Rp. 6.420.579.000

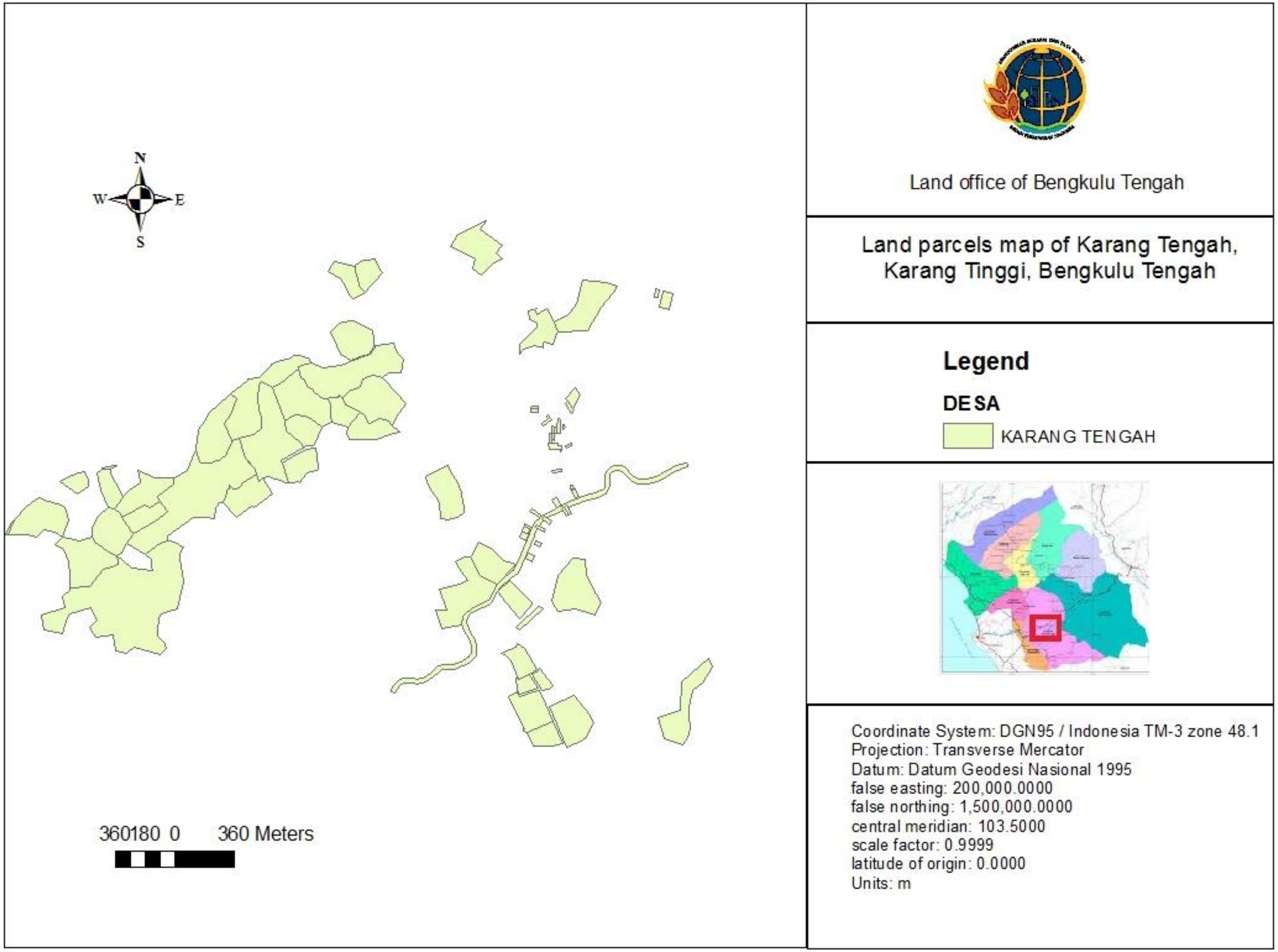
KODE	PROGRAM/ KEGIATAN/ OUTPUT/ SUBOUTPUT/ KOMPONEN/ SUBKOMP/ AKUN/ DETIL	PERHITUNGAN TAHUN 2016			SD/ CP
		VOLUME	HARGA SATUAN	JUMLAH BIAYA	
(1)	(2)	(3)	(4)	(5)	(6)
	- ATK	5,00 PKT	5.000	25.000	
F	*PENGGAMBARAN LAPANGAN*			*78.000*	
521219	Belanja Barang Non Operasional Lainnya (KPPN.016-B E N G K U L U)			68.000	PNBP
	- Biaya Penggambaran Lapangan	5,00 BID	13.603	68.000	
521811	Belanja Barang Untuk Persediaan Barang Konsumsi (KPPN.016-B E N G K U L U)			10.000	PNBP
	- ATK	5,00 PKT	2.000	10.000	
G	*PEMBUATAN PETA BIDANG TANAH/SURAT UKUR*			*25.000*	
521811	Belanja Barang Untuk Persediaan Barang Konsumsi (KPPN.016-B E N G K U L U)			25.000	PNBP
	- ATK&Penunjang Komputer	5,00 PKT	5.000	25.000	
H	*PENYIMPANAN WARKAH*			*25.000*	
521811	Belanja Barang Untuk Persediaan Barang Konsumsi (KPPN.016-B E N G K U L U)			25.000	PNBP
	- Atk dan Penunjang Komputer	5,00 BID	5.000	25.000	
I	*PEMBULATAN*			*6.000*	
521219	Belanja Barang Non Operasional Lainnya (KPPN.016-B E N G K U L U)			6.000	PNBP
	- pembulatan	1,00 PKT	6.000	6.000	
057	**LAYANAN PENGUKURAN BATAS BIDANG TANAH**			**262.809.000** U	
A	*PEMERIKSAAN KELENGKAPAN BERKAS & ENTRY DATA*			*1.680.000*	
521811	Belanja Barang Untuk Persediaan Barang Konsumsi (KPPN.016-B E N G K U L U)			1.680.000	PNBP
	- Belanja Barang	840,00 PKT	2.000	1.680.000	
B	*PERSIAPAN PENGUKURAN*			*19.272.000*	
521219	Belanja Barang Non Operasional Lainnya (KPPN.016-B E N G K U L U)			10.872.000	PNBP
	- Biaya Persiapan Pengukuran Lapangan	840,00 BID	12.944	10.872.000	
521811	Belanja Barang Untuk Persediaan Barang Konsumsi (KPPN.016-B E N G K U L U)			8.400.000	PNBP
	- Belanja Barang	840,00 PKT	10.000	8.400.000	
C	*PENGUKURAN LAPANGAN*			*205.833.000*	
521219	Belanja Barang Non Operasional Lainnya (KPPN.016-B E N G K U L U)			205.833.000	PNBP
	- Biaya Pengukuran Lapangan	840,00 BID	245.040	205.833.000	
D	*PERHITUNGAN LAPANGAN*			*15.072.000*	
521219	Belanja Barang Non Operasional Lainnya (KPPN.016-B E N G K U L U)			10.872.000	PNBP
	- Biaya Perhitungan Lapangan	840,00 BID	12.944	10.872.000	
521811	Belanja Barang Untuk Persediaan Barang Konsumsi (KPPN.016-B E N G K U L U)			4.200.000	PNBP
	- Belanja Barang	840,00 PKT	5.000	4.200.000	
E	*PENGGAMBARAN LAPANGAN*			*12.552.000*	
521219	Belanja Barang Non Operasional Lainnya (KPPN.016-B E N G K U L U)			10.872.000	PNBP
	- Biaya Penggambaran Lapangan	840,00 PKT	12.944	10.872.000	
521811	Belanja Barang Untuk Persediaan Barang Konsumsi (KPPN.016-B E N G K U L U)			1.680.000	PNBP
	- ATK	840,00 PKT	2.000	1.680.000	
F	*PEMBUATAN PETA BIDANG TANAH/SURAT UKUR*			*4.200.000*	

Appendix 6.

a. Parcel Boundaries Map of Nakau from Existing data



b. Parcel Boundary Map of Karang Tengah from existing data



c. Parcel boundaries map of Waru from existing data