USING UNMANNED AIRCRAFT SYSTEM IMAGES TO SUPPORT CADASTRAL BOUNDARY DATA ACQUISITION IN INDONESIA

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February, 2016

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Enschede, The Netherlands, February, 2016

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Land Administration

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ABSTRACT

Accelerating the process of land registration is a key issue in developing country like Indonesia. However, existing methods with terrestrial measurements for surveying and mapping activities are slow-paced and might require few more decades for completion. Increasing demand for information about land matters necessitates development of an optimal "fit-for-purpose" approach that meets the needs of society today. Technologies like Unmanned Aircraft Systems (UAS) can be seen as a worthy alternative for data acquisition to speed up land registration process. This research deals with sequential activities carried out to ascertain the use of UAS technology for cadastral boundary data acquisition in Indonesia. After a comprehensive review of requisites for cadastral boundary data survey and UAS regulation in Indonesia, various requirement elements were derived to design a UAS based image approach. The new designed approach utilizes participatory boundary mapping for boundary delineation, therefore boundary demarcation activity is not included in this method. By comparison with the existing terrestrial method, the UAS based image approach showed a higher perceived involvement of the community and indicated an efficient improvement on cost and duration and resulted in a high accuracy UAS ortho-photo. This ortho-photo can be used to produce the output with the similar accuracy levels. Given that the approach was triggered by substantial benefits offered by UAS, deeming it as a revolutionizing tool in land administration, enhancing it by integration of latest technologies in data collection and information systems opens up the possibilities towards an improved land administration systems.

Keywords: *Cadastral Survey, Boundary Survey, Parcel Boundary, UAS, Participatory Boundary Mapping, Indonesia*

ACKNOWLEDGEMENT

I would like to begin my recognition to the staff at Faculty of Geo-Information Science and Earth Observation (ITC). Humble gratitude to all my lecturers and guest lecturers who have been contributed in my research and academic period at ITC, for introducing, guiding and facilitating me and my colleagues to find the fit-for-purpose way in securing the humanity from land problems. Thank you for giving both knowledge and inspiration. One special thanks to Dr. Mila Koeva for her considerate gesture towards my work. Also to Caroline Gevaert, for nicely responding my last minute doubts. Knowing and meeting you all in person is priceless for me.

A sincere appreciation to the two members of the faculty with significant role in this thesis, to both of my "super" supervisors for always welcoming me at your best, spared your time for the 24/7 correspondences, encouraged me, and to be sure for your contribution to my work. To Dr. Rohan Mark Bennett, I recall your friendliness when clueless me came over your office asking you questions regarding this topic, not to forget your remarkable words in the beginning of this project that I should have a deep interest towards my research, which then has developed my profound personal passion and enthusiasm over the topic ever since. To keep me on track, you guided me by giving advices, constructive feedbacks, recommended readings, and also your artsy-scratches-full-of-ideas which had been very helpful yet meaningful for this entire project. I am truly grateful to have you as my guru. To Dr. Francesco Carlo Nex, the recommendations, suggestions, and explanations you gave were not just responding my doubts but also unfolding the tangled knowledge that I needed the most. Despite the distressing first impression I had on SfM lecture, it was beyond my expectation to get a chance working with you who then filtered the necessary technical know-how to support my research. I am so thankful to have you as my second supervisor.

I would also like to express my gratitude to the people of Nusa Tenggara Barat (NTB), Indonesia. Everyone I met from the Regional Office of National Land Agency (BPN) NTB and the local people in Lunyuk Ode Village who went beyond what was needed. To Mohammad Tanzil, the man who provided me everything and offered random discussions in the field from the technical matter of drone to the bitter sweet of life wandering without co-pilot still, and patiently responding my unfinished doubts and questions even from thousand miles away. To Ahmadin and Agus Martana, teamed up with you two in the field was amazing. To the Regional Office of *BPN NTB* and Land Office of Sumbawa Besar, I hope this work meets the preferences and expectations of the institution. People in Lunyuk Ode, all the respondents, Mr. and Mrs. Hermansyah "Gabung" – it was an unforgettable moment to feel such a warm-hearted welcome and pure kindness as this jetlagged researcher was wandering around your land.

Also to all of my LA classmates – esp. Innocent Rubanje, Janvier Muhimpundu, Julinda Dyli and Yuangen Jiang, all "teman-teman" Indo – esp. Asgan Nasrullah, Kinskij Boedihardja, and Triyoga Widiastomo for the brief discussions and dry humour in between coffee break, all amigos in ITC Faculty, and special one to Ipsit Dash who brought me back the desire of living life to the fullest. I'm so blessed to be granted a bunch of experiences through international culinary and stories from my amazing worldwide colleagues. Sincere gratitude also to Albertus Yogo, Nurul Huda, and Dina Citra –office colleagues who gave the essential supports for this work, to Ernis Lukman and Maria Christina Kurniawati – who kept asking how is the research going, and to M. H. Prasetyo – who indirectly led me here, dankjewel and rest in peace.

Last but not least, to my brothers: Muhammad Maulana and Muhammad Larry Izmi, to my sister Wini Rahayu and to beloved nephew Attila Sultan Muhammad – for the unconditional love and support.

In dedication to my Ibu Herlina Warganegara and Ayah Syamsurrizal,
who have been passionately giving, loving and inspiring in such a way that made me who I am today.

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ABBREVIATIONS

ATR	*Agraria dan Tata Ruang* (Agrarian and Spatial Planning)
BAL	Basic Agrarian Law
BPN	*Badan Pertanahan Nasiona*l (National Land Agency)
CoFLAS	Cost and Financing of Land Administration Services
CORS	Continuously Operating Reference Station
CP	Control Point
ETS	Electronic Total Station
GCP	Ground Control Point
GCS	Ground Control Station
GNSS	Global Navigation Satellite System
HRSI	High Resolution Satellite Imagery
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
ID	Identification/Identifier
IDR	Indonesian Rupiah (Currency Unit, ISO)
ITC	Faculty of Geo-information and Earth Science —former International Training Center
Kantah	*Kantor Pertanahan* (Land Office)
Kanwil	*Kantor Wilayah* (Regional Office)
LAS	Land Administration System
MoT	Ministry of Transportation
MSc	Master of Science
NTB	Nusa Tenggara Barat
Pusdatin	*Pusat data dan Informasi* (Center of Data and Information)
RMSE	Root Mean Square Error
ROA	Remotely Operated Aircraft
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
RTK	Real Time Kinematic
STDV	Standard Deviation
SWOT	Strength Weakness Opportunity Thread
UAS	Unmanned Aircraft Systems
UAV	Unmanned Aerial Vehicle
USD	United States Dollar (Currency Unit, ISO)
UVS	Unmanned Vehicle Systems

1. INTRODUCTION

1.1. Background

Recording information about land tenure is known as the process of land registration. There are 3 types of information that are recorded in a land registration process: information about people, information on the nature of those interests, and information about the land parcels (Nichols & McLaughlin, 1990). This information plays an important role in the community, where it is considered as a tool to stimulate the economic and social development of a country by giving legal security and protection that can be used for the population census, taxation, food security, development planning, and so on.

It is important to note that land registration is different in every country: Various geographical and climate conditions, characteristics of the people, capacity in technology, cultural and historical backgrounds, and also religious beliefs are some factors which create these differences. Problems often occur where the country has limited financial resources and human capacity – issues that many developing countries have to face.

Indonesia is one of the developing countries that have been undertaking land registration since 1960. Achmad (2004) explained how land registration in Indonesia reached the 27 million certificates in 2004, 44 years after the first implementation of the system. According to the Ministry of Agrarian and Spatial Planning of Indonesia (2016) nowadays 44.982.124 parcels are registered. In short, it took 11 years to register around 18 million parcels.

Speeding up land registration is an urgent issue with many problems to overcome. Anshari (2007) concluded that it needs the application of the newest technology in survey and mapping as well as more involvement of community to overcome problems. With the current method, where all physical data from the survey and mapping activities resulted from terrestrial measurement, 48 million parcels are still to be certified (Abidin et al., 2015). Consequently, at current rates, Indonesia would still need around 33 more years to complete registration.

Triggered by the increasing need of the information about land in many fields, a number of projects about improving land registration are being held by many parties involved in land matters. Activities during the land registration processes such adjudication, demarcation, surveying, and recording of land information become the focus of improvements relating to saving costs and time. It was elaborated by Enemark (2013), that the functions of land administration may put different requirements and vary depending on the geography and density of the use of land. Therefore, when determining technology and investment choices, the approach design should be "fit-for-purpose" that meets the needs of society today and can be incrementally improved over time – rather than following the existed standards (Enemark, Clifford, Lemmen, & McLaren, 2014).

Eisenbeiss & Grün (2009) outline Unmanned Aircraft Systems (UAS) as a new technology that can be used in data acquisition under different environmental conditions worldwide. The system works like any other remote sensing system where some sensors are set up in the platform, in this case UAS as the platform, and we can get images for various purposes as a result.

UAS has some major advantages such as the ability to access areas without physiological limitations, to provide real-time and fast data acquisition, and for some applications it can be less expensive than manned aircrafts. Manyoky, Theiler, Steudler, & Eisenbeiss (2012) concluded that despite the limitation factors on image orientation accuracy, UAS are able to quickly observe the surface of areas at low flying altitude while still meeting the accuracy requirements of cadastral surveying. Mumbone (2015) also discovered that UAS is ideal for adjudication purposes and first registration, specifically in customary communities.

Therefore, although using the UAS is not yet common in land registration, it appears to be a promising tool that could support cadastral boundary data acquisition and increase the amount of registered land in Indonesia. However, further research is needed on the potential policy, legal, institutional, and technical changes to the existing land registration methods – and the impact of cost, speed, and accuracy.

1.2. Justification

UAS can be used for mapping and surveying activities at lower costs than the cost of satellite or manned aircraft images (Pérez, Aguera, & Carvajal, 2013), and lower than conventional total station or GNSS rover prices (Volkmann & Barnes, 2014). Therefore UAS appear to be another option for land registration purposes, especially for cadastral data acquisition activities.

Several studies have already focused on UAS application for cadastres. Rokhmana, Soetaat, Tjahyadi, & Sumarto (2010) concluded that the different values for rice fields using images from UAS-based photogrammetry are still tolerable regarding the land registration requirements in Indonesia. Another study compared usage of UAS with tachymetry/GNSS methods for cadastral surveying with respect to time expenditure, accuracy, and completeness (Manyoky et al., 2012). These two studies focused on accuracy assessment of the boundaries resulting from UAS – and whether the results meet cadastral surveying requirements or not.

There were also some modification and innovation studies for UAS in cadastral application. Sadikin, Saptari, & Abdulharis (2014) carried out a modification to an existing UAS surveying method, to solve the geometric accuracy problem, as a result of the instability of the vehicle while taking the photos. This modification was considered to be necessary due to the fact that geometric accuracy is highly important for land parcels mapping. In addition, Rijsdijk et al. (2013) revealed the utility of UAS in the juridical verification process of cadastral ownership, whilst Mumbone (2015) examined whether it can overcome the prevailing challenges associated with conventional mapping techniques to map the customary land parcel boundaries. Complementary with the previous idea, these studies also focused on how UAS could meet the required accuracy for cadastral applications, or make use of the advantages of UAS.

Meanwhile, according to the United States Agency International Development (2010), it can take six to twelve months to register rural land rights in rural areas, as the case studies conducted in Sulawesi, Indonesia revealed. Thorburn (2004) revealed that citizens of Indonesia's attempts to acquire title for land are often frightfully expensive. This was an impact of the system of land registration in Indonesia which relied only on ground measurement for cadastral boundary data acquisition, and thus resulted in high demand of human resources with expertise to execute the measurement. High cost also appears as an issue since the cost of ground measurement is considered high. Meanwhile, generating general boundaries from imagery has dependency on high-resolution imagery, which could not be fulfilled caused by many obstacles such as the high price of image and cloud cover conditions.

Taking these problems of land registration in Indonesia into consideration, this study seeks to develop a new approach using UAS to support the cadastral boundary data acquisition. Specifically, the focus will be on comparing its viability against conventional methods, in terms of cost, duration, and spatial accuracy.

1.3. Research Problem

The current cadastral boundary data acquisition process in Indonesia does not support fit-for-purpose land registration in Indonesia. UAS are a new approach for capturing spatial information which is argued to have utility for cadastral purposes. However

It remains uncertain whether UAS will support a fast, cheap, and appropriately accurate land registration for the context of Indonesian cadastral boundary acquisition.

1.4. Research Objective

Responding to the research problem, the main objective of this study is:

To ascertain whether UAS *technology when used for cadastral boundary data acquisition in Indonesia is fit-for-purpose in terms of duration (time), cost of the process, and spatial accuracy achieved.*

1.5. Research Questions

In order to achieve the overarching objective and inspired by Mumbone (2015), sub-objectives and research questions are defined:

1. *To review existing cadastral boundary data acquisition process and current status of UAS usage in Indonesia*
   1.1. What are the policies, policies makers involved, regulations, technologies, constraints and characteristics of existing approach in acquiring cadastral boundary data in Indonesia?
   1.2. What are the policies, regulations, restrictions, constraints, and development of UAS technology in Indonesia?
2. *To develop a UAS based image approach for cadastral boundary data acquisition in Indonesia*
   2.1. What does a UAS based image approach for cadastral boundary data acquisition look like and what steps are involved?
   2.2. What are the spatial accuracy achieved, cost, and duration of the new developed approach?
3. *To evaluate UAS based image approach for cadastral boundary data acquisition in Indonesia in terms of the elements of fit-for-purpose.*
   3.1. What is the result of the evaluation?
   3.2. What are the advantages and limitations of the new developed approach?
   3.3. What is the recommendation for future improvements?

1.6. Conceptual Framework

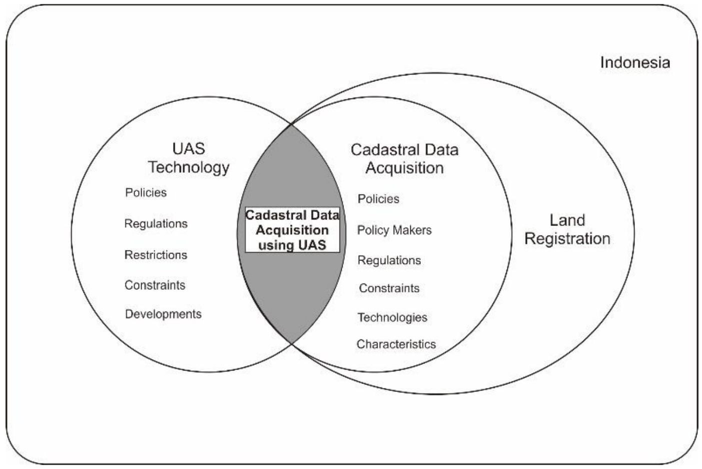

Figure 1: Research conceptual framework

1.7. Methodology

The design research to develop a UAS based image approach for cadastral boundary data acquisition included three main activities: review, develop the new approach, and evaluate it. These activities were conducted using different methods i.e. literature and document review, interviews, prototyping, image acquisition and Ground Control Points (GCPs) collection, participatory boundary mapping, and a comparative study. Through literature review and interview, a comprehensive observation on the requirements on cadastral boundary needs and UAS regulations were held. With the elements of requirements collected, approach using UAS was developed and applied in the case study area.

The final evaluation was based on a comparison of the effectiveness and efficiency of two different approach: the new developed approach and the existing one – according to Kumar (2011) in such situations a comparative study is appropriate. Through a comparative study, the cases treated were assumed to be comparable with respect to the original level of comprehension. In this research, the same objects meant to be compared were parcels from the same study area. It exposed each approach to another that follows up an after observation. A secondary dataset of cadastral data of the study area, which was conducted using the existing approach was obtained from the Regional Office of National Land Agency in Nusa Tenggara Barat Province (from now on "*Kanwil BPN NTB*"). This dataset was compared with the other dataset which obtained through a field observation by testing the new developed approach.

Figure 2 illustrates the work steps and methodological framework that were used to achieve the objectives and answer the corresponding research questions.

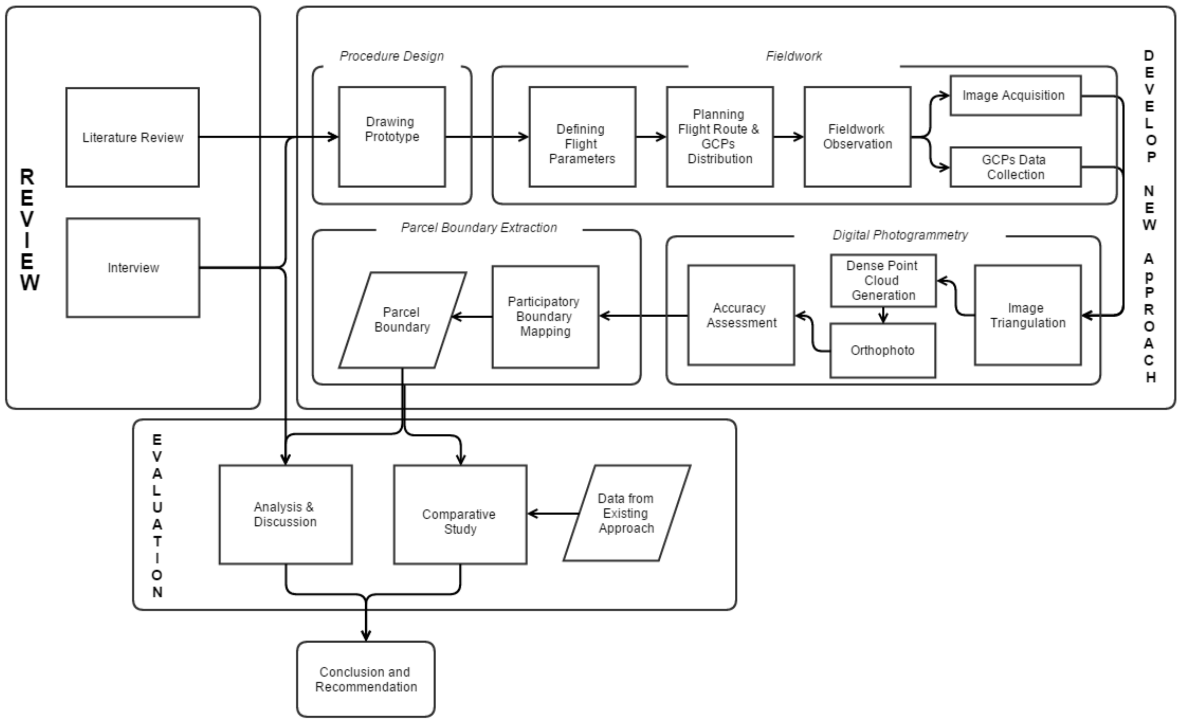

Figure 2: Methodological framework

1.8. Research Matrix

A research design matrix was arranged to give an overview of the sequence of the research including methods to be carried and data required.

Table 1: Research design matrix

No.	Research Sub Objectives		Research Questions	Techniques of Analysis	Required Data and Software	Anticipated Result
1.	To review existing cadastral boundary data acquisition process and current status of UAS usage in Indonesia.	1.1. 1.2.	What are the policies, policies makers involved, regulations, technologies, constraints and characteristics of existing approach in acquiring cadastral boundary data in Indonesia? What are the policies, regulations, restrictions, constraints, and development of UAS technology in Indonesia?	▪ Literature Review ▪ Text Based Method	Literature and Interview Transcripts	▪ List of policies, policies makers involved and regulations; ▪ List of technologies, constraints and characteristics of existing approach in acquiring cadastral boundary data in Indonesia and discussion; ▪ List of policies, regulations and restrictions of development of UAS in Indonesia; ▪ List of constraints of UAS technology and discussion.
2.	To develop a UAS based image approach for cadastral boundary	2.1.	What does a UAS based image approach for cadastral boundary data acquisition look like and what steps are involved?	▪ Literature Review; ▪ Prototyping;	▪ Data: Literature, UAS Flight Plan,	▪ Use case diagram of UAS based image approach for cadastral

No.	Research Sub Objectives	Research Questions	Techniques of Analysis	Required Data and Software	Anticipated Result
	data acquisition in Indonesia	2.2. What are the spatial accuracy achieved, cost, and duration of the new developed approach?	▪ Field Observation; ▪ Participatory Boundary Mapping.	GCPs Plan, UAS Imagery; ▪ Software: *Pix4D Mapper*, *ArcGIS*, *Trimble General Survey*; ▪ Hardware: UAS, GNSS RTK Receiver.	boundary data acquisition ▪ Geo-Referenced UAS; Imagery; ▪ Accuracy achieved from the new developed approach.
3.	To evaluate UAS based image approach for cadastral boundary data acquisition in Indonesia in terms of the elements of fit-for-purpose.	3.1. What is the result of the evaluation? 3.2. What are the advantages and limitations of the new developed approach? 3.3. What is the recommendation for future improvements?	▪ Literature Review; ▪ Text Based Method from; ▪ Comparison with Data from Existing Approach (GIS Analysis).	▪ Data: Literature, Interview Transcripts, Primary Data (from the UAS based image Approach), Secondary Data (from the Existing Approach); ▪ Software: *TextSTAT*, *Wordle*, *Ms. Excel*, *ArcGIS*.	▪ List of the evaluation result; ▪ List of the advantages and limitations of the new developed approach; ▪ List of recommendations for future improvements.

2. THEORETICAL CONCEPTS

2.1. Describing UAS

Different terms have been used to describe the system of unmanned aircraft. It was most likely affected by the different requirements and concepts between the military and civilian systems or have regulatory/legal importance (Dalamagkidis, 2015c). UAS or Unmanned Aircraft Systems has been preferred to describe an unmanned aircraft by the Federal Aviation Administration (FAA), but there are several other terms that are also used and have the same meaning, for example: drone, Unmanned Aerial Vehicle (UAV), Remotely Operated Aircraft (ROA), Remotely Piloted Aircraft (RPA), Remotely Piloted Aircraft System (RPAS), and Unmanned Vehicle Systems (UVS).

Various definitions have been proposed to describe UAS. Federal Aviation Administration (FAA) (2008) defined the unmanned aircraft as "A device used or intended to be used for flight in the air that has no on-board pilot. This includes all classes of airplanes, helicopters, airships, and translational lift aircraft that have no on-board pilot. Unmanned aircraft are understood to include only those aircraft controllable in three axes and therefore, exclude traditional balloons". Illustrated also by van Blyenburgh (1999) as "uninhabited and reusable motorised aerial vehicles, which are remotely controlled, semi-autonomous, autonomous, or have a combination of these capabilities, and that can carry various types of payloads, making them capable of performing specific tasks within the earth's atmosphere, or beyond, for a duration, which is related to their missions", UAS permits to encompass systems with certain number of common features. A definition to simplify the term was given by (Dalamagkidis, 2015c) that it refers to "a pilotless aircraft, a flying machine without an on-board human pilot or passengers". Went beyond to the use of UAS as a new photogrammetric measurement tool, Eisenbeiss & Grün, (2009) described it as "photogrammetry system which is equipped with a photogrammetric measurement system introduces new (near-) real time application and low-cost alternatives to the classical manned aerial photogrammetry".

Referred as a reusable aircraft that has the ability to perform a variety of missions in (Keane & Carr, 2013), UAS was mentioned to have been around much longer than most people realize. Unmanned aircraft appeared around the time of the First World War (1916) and was developed for military purposes considering its potential benefits and efforts to adapt flying machines to operate without a pilot on board stated (Dalamagkidis, 2015a). In recent years the use of UAS has been increased and expanded to various applications aside from military business. Categorized into 3 by van Blyenburgh (2015), civil drone use is given in Table 2. The first category – commercial and non-commercial – is the civil common operation of UAS including the corporate operations; second category – flight training – is the civil activities with purpose of practising UAS operation; the last category is other works which are not covered by the first two categories, e.g. testing and demonstration flight. A showcase of the civil activities using drones was given in New America (2016) that UAS is now applied for agriculture, archaeology, armed conflict monitoring, cargo, community mapping, disaster response, environmental surveying, search and rescue, training, and wildlife surveying. In geomatics fields, UAS now became a common platform for data acquisition (Nex & Remondino, 2013).

Table 2: Civil RPAS aerial work categories (van Blyenburgh, 2015)

<table>
<tr><th colspan="2"></th><th>Explanation of Terms</th></tr>
<tr><td rowspan="2">Commercial & Non-Commercial
(including Corporate Operations)

- Aerial Advertising
- Aerial Inspection
- Aerial Monitoring
- Aerial Observation & Surveillance
- Aerial Patrol & Spotting
- Aerial Photography, Video, Cinema
- Aerial Survey & Mapping (Photogrammetry)
- Aerial Spraying & Dispensing
- Research & Scientific
- Aerial Search & Rescue Assistance</td><td>Flight Training / Instruction

- Duo (student instruction by licensed pilot)
- Solo (unaided student flight)
- Check (verification of qualification of pilot license holder)</td><td rowspan="2">Inspection: Examination with the intent to find faults, errors, problems, malfunctions or specific phenomena.
Monitoring: Observing on a regular basis over a period of time.
Observation: Examination of an activity, person, group, area or phenomena.
Patrol: Searching for a specific activity, person, group or phenomena.
Spotting: Looking for & noting geographical coordinates of an object or activity or phenomena.
Surveillance: Close observation of an activity, person, group, area or phenomena.
Survey: Detailed inspection of a geo-referenced section of the earth's surface (including structures) with the purpose to study or measure altitudes, angles, distances phenomena on the land and the structures flown over.</td></tr>
<tr><td>Other Miscellaneous

- Test / Experimental
- Demonstration
- Ferry / Positioning
- Air Show / Race</td></tr>
</table>

2.1.1. System Overview

Although the term UAS being used, the system consists of aircraft as the platform and Ground Control Station (GCS) as the controller. Acquiring image using UAS is possible by installing a camera on the platform. This installed camera will obtain images during the flight which is controlled by the GCS. The data received by the GCS from the instruments is either processed on-site or forwarded to a processing centre (Everaerts, 2008). The Guidance, Navigation, And Control (GNC) system which consists of the airborne and ground component is illustrated in Figure 3.

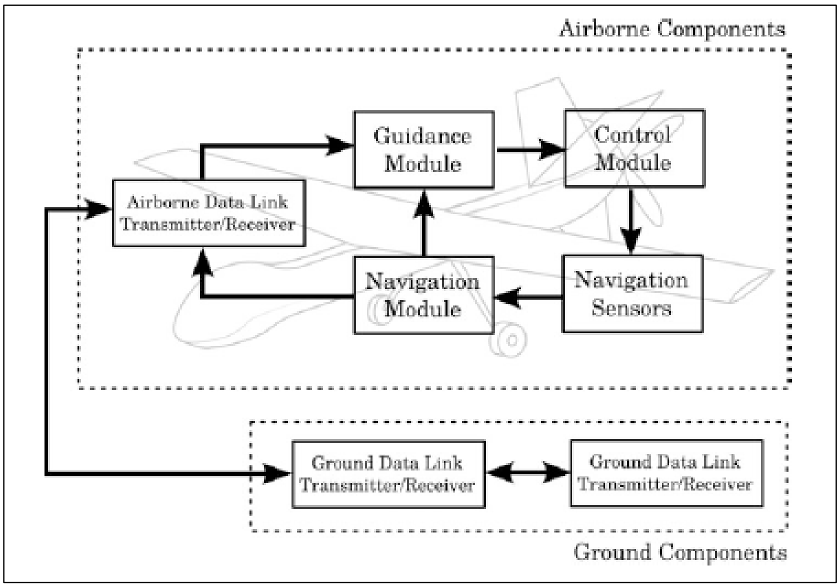

Figure 3: Unmanned aerial system (UAS) concept of operation (Elkaim, Adhika, & Lie, 2015)

It was mentioned in (Dalamagkidis, 2015b) that "a large number of metrics have been used for UAS classification, including Mean Take-Off Weight (MTOW), size, operating conditions, capabilities, or any combination of these and other characteristics". UAS can also be classified for its aerodynamic and physical features which is given with its evaluation of one to another by (Nex & Remondino, 2013) in Table 3.

Table 3: Evaluation of some UAV platforms employed for geomatics with value 1 (low) to 5 (high) (Nex & Remondino, 2013)

	Kite/ balloon	Fixed wing		Rotary wings	
		Electric	ICE engine	Electric	ICE engine
Payload	3	3	4	2	4
Wind resistance	4	2	3	2	4
Minimum speed	4	2	2	4	4
Flying autonomy	–	3	5	2	4
Portability	3	2	2	3	3
Landing distance	4	3	2	4	4

2.1.2. UAS for Image Capture

The procedure of image acquisition and processing of UAS is started by the flight planning. The mission (flight and data acquisition) is normally planned in the lab with dedicated software, starting from the knowledge of the area of the interest, the required Ground Sample Distance (GSD) or footprint, and the intrinsic parameters of the on board digital camera (Nex & Remondino, 2013). Flying height and camera perspective centres (waypoints) which will determine the image scale and the object details are fixed in this step. The flight itself can be done in 3 modes: manual, assisted and autonomous mode. The choice of mode is affected not only by the environmental conditions and the platform, but also the navigation system of the mission.

After the image acquisition, a fundamental procedure required is camera calibration and image orientation. It requires the extraction of visible common features in images, which are so called tie points and are followed by a bundle adjustment. Then, after a set of images are oriented, it can be processed using the following steps, such as 3D modelling, ortho-image, feature extraction, etc., which can be seen as the whole procedure in Figure 4 by Nex & Remondino (2013).

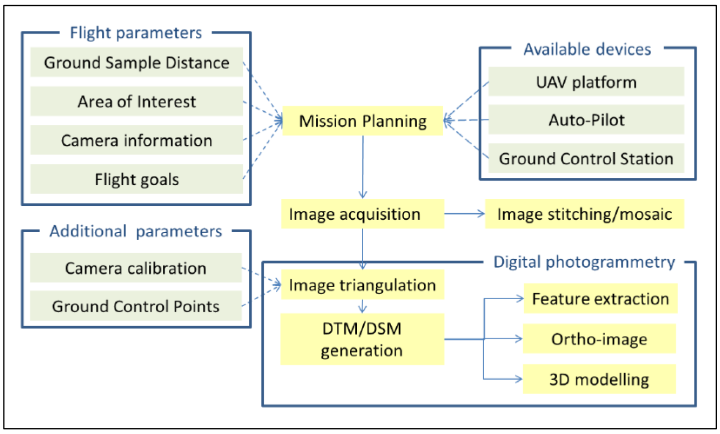

Figure 4: Typical acquisition and processing pipeline for UAV images by Nex & Remondino (2013)

Image Accuracy

The procedure of capturing imagery using uses photogrammetry principles that involve systematic and random errors came from a variety sources. Furthermore, any model representation of reality will never be "exact": there will always be some difference between the end product of any surveying or photogrammetric project and "the truth" (Sedorovich, Hara, & Schuckman, 2010). The analysis towards the accuracy achieved from the image is usually conducted using the pre-marked control points which are surveyed using terrestrial measurement. The terms used to describe this pre-marked control points to evaluate the accuracy can be confusing. From Sedorovich et al. (2010) it was known that the definition of Ground Control Points (GCPs) which are used for initial geo-referencing are identifiable points in real space (on the ground), whose locations are known, and they are used to verify positioning of map features, aerial images, or remotely sensed images. Beside the GCPs, checkpoints which are also referred as validation points, survey points and reference points are also introduced to perform an independent, quantitative assessment of image location error (Sedorovich et al., 2010).

2.1.3. Advantages and Disadvantages of UAS

Earlier UAS technology was unreliable and has now much improved and become more reliable, although there do still remain some problems (Vachtsevanos & Valavanis, 2015). With the fact that it is capable to fly gathering information with minimal human intervention, UAS appears as a transformative technology in certain aspects (Kakaes et al., 2015). Remondino, Barazzetti, Nex, Scaioni, & Sarazzi (2011) mentioned that the great advantage of actual UAS is the ability to quickly deliver high temporal and spatial resolution information, to allow a rapid response in a number of critical situations where immediate access is crucial, and to be used in high risk situations and inaccessible areas, although they have some limitations in particular for the payload, insurance, flight endurance and stability.

2.2. Unpacking Cadastral Boundary Surveying

2.2.1. Cadastral System

It was mentioned by Bogaerts & Zevenbergen (2001) that "A cadastral system consists of two parts, the land registration and the cadastre". To understand the concepts of cadastral system, definitions related to this term will be given. Zevenbergen (2002) defined land registration as "a process of official recording of rights in land through deeds or title (on properties)", and Silva & Stubkjær (2002) described cadastre as "a systematic and official description of land parcels, which includes for each parcel a unique identifier". Meanwhile the description includes written attributes of each parcel, a large-scale map that provides information on parcel boundaries is used as the means of identification.

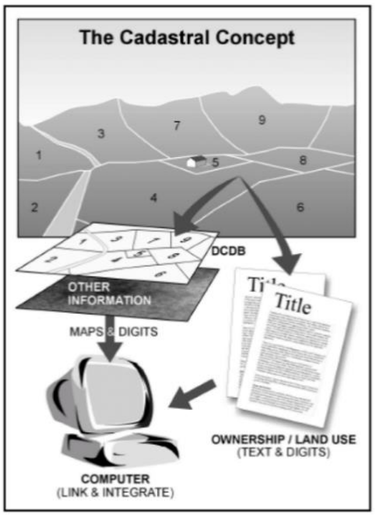

Figure 5: The cadastral concept (Williamson & Wallace, 2007)

A remark on cadastral systems was elaborated by Enemark (2009): it was a system which included the interaction between the identification of land parcels and the registration of land rights, and also supported the valuation and taxation of land and property, and the administration of present and possible future use of land. To simplify the concept of cadastre, Williamson & Wallace (2007) illustrated it as "a map of the parcels and land arrangements now available in digital form in computers showing how a society organises its land into useable pieces with interconnecting roads and services" (see Figure 5). Together with surveying, cadastres is an antecedents of the land administration field, a multi-discipline endeavour with a focus on land management, delivery and organisation (Williamson & Wallace, 2007).

2.2.2. Cadastral Boundary Survey Overview

A term generally used to describe the gathering and recording of data about land parcels is cadastral surveying. It is concerned with geometrical data capture, especially the size, shape, and location of each land parcel (Dale & McLaughlin, 1999). A parcel as one of the elements recorded in cadastral systems is defined by the boundary indicators. Boundaries of parcels can be defined by physical demarcation on the ground or by a mathematical description usually based on a co-ordinate system (International Federation of Surveyors (FIG), 1995).

Boundaries may be specific (sometimes referred to as "fixed"), in which case the precise line of the boundary can be determined, alternatively they may be general, in which case the official register only shows the approximate line of the boundary, precise details of which can only be established by further investigation on the ground (Dale & McLaughlin, 1999). Fixed boundaries are the marked boundaries agreed by all parties, which then precisely surveyed, whilst the general boundaries are the natural or man-made visible features which are used as the approximate location identification. Both parcel boundary types use a unique identifier as the main identifier of cadastral surveying. The unique identifiers – distinguished by its name, alphanumeric or location identifiers – are aimed for recognizing, selecting, identifying, and arranging information to facilitate organized storage and retrieval of parcel records (National Research Council (U.S.), 1983).

Cadastral Boundary Surveying Techniques

Cadastral surveying operations essentially includes the determination of the boundaries on the ground, the survey of the boundaries, and the demarcation of the boundaries (Larsson, 1991). According to Dale & McLaughlin (1999) basically, there are two broad categories of surveying technique: field survey and photogrammetry, and two categories of output: graphical and digital. But the number of techniques and (boundary) data acquisition methods has dramatically increased in the last 30 years (Scaioni, Perko, & Veronez, 2014). Scaioni et al. (2014) mentioned that since the integration to computers and electronic devices, the traditional optical instruments for terrestrial measurement have developed. And new sensor techniques such as Global Navigation Satellite Systems (GNSS), digital photogrammetry and laser scanning sensors became available to be used from ground-based stations, mobile terrestrial vehicles, and low-altitude aerial platforms. Overall, it can be comfortably stated that a modification to the procedure for cadastral surveying was created by digital data.

The basic concepts of surveying for cadastral purpose are the same with the original principles of surveying, which is defined as "the art of making measurements of the relative positions of natural and man-made features on the earth's surface" (Bannister, Raymond, & Baker, 1998). A simple illustration on the basic concept is given in Figure 6. Where on any area of land to be measured, two points are possible to be chosen and then the distance line between them is measured and scaled on paper. "Other points can be located relative to the line by taking two other measurements, which can of course be similarly drawn to scale on the paper, and in this way a map is constructed. The two measurements can consist of two distances, one distance and an angle or two angles, two measurements. A and B representing in each case

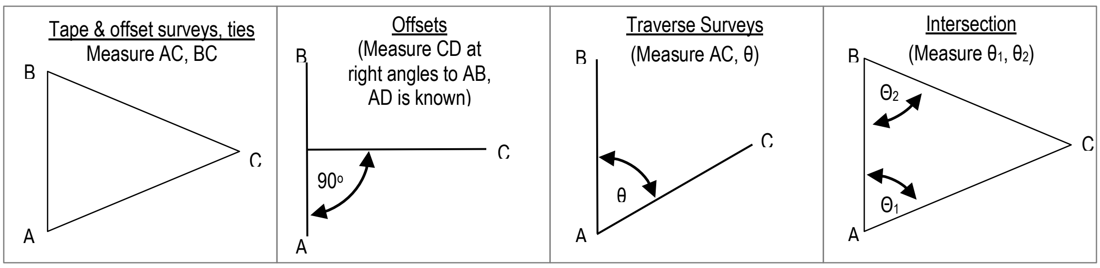

Figure 6: Basic principles of surveying (Bannister et al., 1998)

the two original points, and C as a point to be located." (Bannister et al., 1998). These concepts are applied for all types of surveying methods, e.g. terrestrial and photogrammetry. Thus, UAS – system with principle of photogrammetry – is also using the basic concepts of surveying.

The points and angles can be measured using several methods and tools. Following the development of technology, tools for the measurement has also been developed, currently most of the surveys are undertaken using measuring tape, theodolites, Electronic Total Station (ETS), Electronic Distance Measuring (EDM), and Global Navigation Satellite System (GNSS) which is more popular as Global Positioning System (GPS). Regarding the data processing, two computational methods exist in the present world of surveying: simple plane survey computations performed on a local orthogonal coordinate system and geodetic computations on a variety of geodetic systems using spherical or ellipsoidal coordinate systems (latitudes and longitudes) (Craig & Wahl, 2003).

2.2.3. Cadastral Boundary Survey in Indonesia

Indonesian land administration is regulated by the *Basic Agrarian Law* (BAL) of 1960 as the National Land Law. The system is run by one government institution: Ministry of Agrarian and Spatial Planning/National Land Agency (ATR Ministry/BPN) – formerly the National Land Agency (BPN), which has 33 Regional Offices (*Kanwil*) and 430 Land Offices (*Kantah*) covering the whole country (Ministry of Agrarian and Spatial Planning of Indonesia, 2015).

Conceptually, land tenure rights status in Indonesia is parted into 2: control rights over land with special authority (public and civil law) and "*ulayat*" or "*adat*" rights – terms used for properties of customary community. There are 5 primary tenures: Ownership, Cultivation Right, Building Right, Using Right, and Management Right (Hutagalung et al., 2012). Although "u*layat*" or "a*dat*" is specifically recognized by the law – and social penalty will be given for its violation, but it is only possible to cadastrally register them as one of the tenure types stated in *BAL 1960*, thus its rights is somehow delimited.

Heryani & Grant (2004) mentioned that the registration of land in Indonesian system is not guaranteed by the state (a negative system), where registers are treated as primary evidence rather than definitive proof. It was elaborated by (Hutagalung et al., 2012) that Indonesia has principles of simple, safe, affordable, sophisticated and open land registration – including adjudication (land registration activities for the first time) and updating and maintenance. "Although the Indonesian system looks quite decent at first sight, the practice is rather different" (Zevenbergen, 2002). A number of land administration problems in Indonesia were highlighted: corruption, arbitrary land seizures, multiple certificates being issued, lack of public knowledge of national land law (Thorburn, 2004). These created disputes, informal environment caused by private conveyancing (Heryani & Grant, 2004), and low internal security for "*adat*" communities (Zevenbergen, 2002).

Boundary Surveying Techniques in Indonesia

In many countries, the techniques that must be used in cadastral surveying are prescribed in the law and in regulations that specify the standards that are to be achieved and the methods that must be used to deliver them (Dale & McLaughlin, 1999). The regulation on survey and mapping activity for land registration purposes indicates the possibility to conduct the data acquisition through other methods beside terrestrial method (e.g. photogrammetric). However, the fact is that on the ground, due to limited base map availability, cadastral surveying is still mainly undertaken with terrestrial methods. Zevenbergen (2002) also mentioned that those boundaries of registered parcels have to be monumented by markers supplied by the National Land Agency (BPN) – now Ministry of Agrarian and Spatial Planning (ATR Ministry). This adds extra costs.

The government also made an arrangement for the implementation of cadastral boundary survey according to the size of the area. Although it is stated that all sporadic measurement is the authority of land office (*Kantah*), for areas of 10 Ha to 1000 Ha, the authority is given to the regional office (*Kanwil*), and the central government is in charge of the boundary survey for areas larger than 1000 Ha. Further explanation about boundary surveying techniques in Indonesia will be explained in Chapter 3.

2.3. Participatory Mapping

Started in the late 1980s, the participatory use of maps has been developing to reach "the goals of placing the ordinary people in the position to generate, analyse, manage, and exchange georeferenced data, and to integrate multiple realities and diverse forms of information to foster social learning and broaden public participation across socio-economics contexts, locations, and sectors" (Rambaldi, 2005). The number of participatory mapping initiatives worldwide are rapidly growing and often referred to in different terms such as participatory mapping, indigenous mapping, counter mapping, and community mapping (International Fund for Agricultural Development (IFAD), 2009). Despite the distinct terms, approaches and tools used, there is a similar thing that linked them: "the process of map-making is undertaken by a group of non-experts who are associated with one another based on a shared interest" (International Fund for Agricultural Development (IFAD), 2009). It was defined in International Fund for Agricultural Development (2009) that participatory mapping is "a map-making process that attempts to make a visible the association between land and local communities by using the commonly understood and recognized language of cartography".

Figure 7: Participatory mapping tools, left to right: using remote sensing images, participatory 3D modelling, ground mapping (International Fund for Agricultural Development (IFAD), 2009)

The tools used for participatory mapping are broadly available nowadays as mentioned in International Fund for Agricultural Development (2009): Ground mapping, participatory 3-D modelling, using aerial and remote sensing images (see Figure 7), GPS mapping, sketch mapping, transect mapping, scale mapping, multimedia mapping, participatory geographic information systems, and internet-based mapping. Rooted from Participatory Learning and Action (PLA) and in Participatory Rural Appraisal (PRA), the innovative practice of Participatory Geographic Information System (PGIS) combines participatory mapping visualisations, Spatial Information Technologies (SIT), spatial learning, communication and advocacy (Rambaldi, Chambers, Mccall, & Fox, 2006).

Ethics in each location, civilization, and occupation are different one to another. Participatory mapping is meant to respond a blend of different moral rules, thus ensuring the implementation of the guide to good practice (Appendix 17) is considerably necessary as an ethical choices for the practitioners (Rambaldi et al., 2006).

Participatory Mapping for Boundary Delineation

Based on the experiences of International Land Coalition (ILC) members which is elaborated by Stefano (2008), one of the participatory mapping initiatives is undertaken with a purpose of adjudicating and registering land rights. The existence of geo-referenced community mapping to gather the spatial knowledge (e.g., PGIS, PPGIS, GPS, ortho-photo mapping, participatory 3-D modelling, satellite imaging) can help rural communities have their land claims recognized by state institutions, particularly where the existing legal framework is receptive to such claims (Stefano, 2008).

With the intent of producing legally acceptable evidence of prior land use, in preparation for negotiating the formal recognition of their ancestral territories, the indigenous communities in northern Canada undertook the participatory mapping with a distinct term "Tenure Mapping", which included the phase of gathering essential data and transferring field data to a scaled base map and producing a final tenure map – a process that requires a computer, printer and appropriate software (Poole, 2006). In the case study of Rwanda Land Tenure Regularisation (Gillingham & Buckle, 2014), the procedure of land demarcation was held encouraging the land owners to make themselves available to guide the committees and para-surveyors, show and agree on the boundaries with their neighbours before the para-surveyors then mark the boundaries of the land parcel on the enlarged photo map (Gillingham & Buckle, 2014)..

2.4. Summary of Chapter 2 – Theoretical Concepts

The research is covering three theme areas: UAS, cadastral boundary surveying, and participatory mapping. In this chapter, the three main concepts of the research construction are delivered to get the basic understanding on each concept. First concept, UAS – a term used to describe an Unmanned Aircraft Systems – consists of airborne components and ground components and functions similar to photogrammetry. It enables the system to capture imageries that can be utilized for various purposes, including surveying in geomatics fields. This chapter also elaborates the concept of cadastral boundary survey, term which essentially includes the determination of the boundaries on the ground, the survey of the boundaries, and the demarcation of the boundaries (Larsson, 1991). Field survey and photogrammetry are the two broad categories of surveying technique (Dale & McLaughlin, 1999), but the basic concepts of surveying for cadastral purpose are the same with the original principles of surveying. Although the photogrammetric technique is said to be possible to conduct for cadastral purpose in Indonesia, the fact on the ground reveals that it is still mainly undertaken with terrestrial method. Through the literatures, practice of participatory mapping – the third concept – has been developed as an alternative way to gather spatial knowledge for adjudication and land registration purpose.

3. REQUIREMENTS – INDONESIAN CADASTRAL BOUNDARY NEEDS AND UAS REGULATIONS

To achieve sub objective 1 and 2, a literature review was conducted. Sub objective 1 sought a comprehensive understanding on the existing procedure of cadastral boundary data acquisition and the current status of UAS in Indonesia, whilst sub objective 2 aimed to develop and test a UAS based image approach for cadastral boundary data acquisition in Indonesia. Therefore to achieve sub objective 1, an inclusive review of laws, policies, policies makers involved, technologies related to existing procedure of cadastral data acquisition in Indonesia, and also regulations about UAS in Indonesia was completed. Similarly to objective 1, a comprehensive review was conducted to answer sub objective 2. This review included a gathering of information and knowledge related to existing works which suitable for developing and testing a UAS based image approach.

3.1. Existing Cadastral Boundary Data Acquisition in Indonesia

To find out about the procedure of cadastral boundary data acquisition in Indonesia, an inclusive review was done and resulted in a list of 15 legislative documents related to the procedure of cadastral boundary data acquisition in Indonesia (see Appendix 1). In Figure 8, a brief description of the hierarchy of legislation in Indonesia, based on *Establishment of Legislation Law* (Republic of Indonesia, 2011), is given to give a better understanding on the legislation in Indonesia.

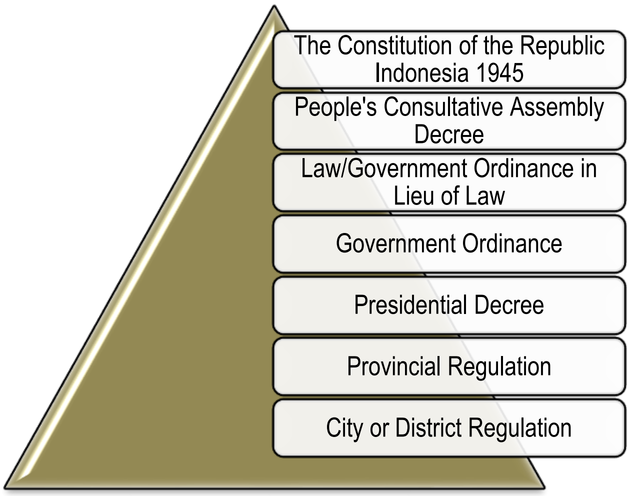

Figure 8: Legislation hierarchy in Indonesia

3.1.1. Policy and Policy Maker

The foundation of the Indonesian Cadastral System is the *Constitution of the Republic Indonesia* (Republic of Indonesia, 1945). Article 33 Clause 3 mentions, "Land, water and natural resources contained therein controlled by the state and used for the prosperity of the people". Therefore the state is in charge on the management of land and the system being managed should be beneficial for the people of Republic Indonesia. Fifteen years later, based on the basic constitution, the government published the *Basic Agrarian Law* (Republic of Indonesia, 1960) which then has become the source of agrarian law in Indonesia ever since. In Part II Article 19 Section 2 of *Basic Agrarian law (BAL) 1960* it was mentioned that activities of surveying, mapping and recording land are included in land registration procedure.

To improve *BAL 1960*, legislation that included the agrarian reform policy were published in 2001 and 2003. The first legislation, *People's Consultative Assembly Decree IX* (Republic of Indonesia, 2001), pointed out the agrarian reform policy and natural resource management in Indonesia. One of the principles mentioned in the decree was to actualize decentralization regarding the authority in agrarian resource management. Specifically, Article 5 noted that one of the agrarian reform policies would be the implementation of land arrangement through the inventory and registration of control, ownership, use and cultivation of land comprehensively and systematically. In addition, *Presidential Decree on National Land Policy* (Republic of Indonesia, 2015b), aimed to implement the *People's Consultative Assembly Decree IX of 2001 on agrarian reform*, was also published. In Article 1 of the Decree, it was mentioned that BPN should perform the acceleration of cadastral mapping by using satellite image and information technology to support the implementation of land reform. The establishment of these 2 decrees showed the government's concern on the importance of registering the whole land in the country was a policy priority.

Furthermore, the State itself, as the executive party regarding the implementation of the national agrarian law was named in *BAL 1960*. Specifically, for land registration purposes, the implementation would follow the Government Regulation on land registration and take the consideration of Agrarian Minister. With respect to *BAL 1960*, the government then established the *Government Ordinance Number 24* (Republic of Indonesia, 1997a) to regulate land registration in Indonesia. According to this regulation, BPN is the executive authorized party to hold the land registry in Indonesia, and therefore should include also the activity of cadastral survey and mapping.

Since the implementation of *BAL 1960*, the authorized agency with the responsibility in land matters has been changing names through time. From the most recent legislation – *Presidential Decree Number 17 on Ministry of Agrarian and Spatial Planning* (Republic of Indonesia, 2015a) and *Presidential Decree Number 20 on National Land Agency* (Republic of Indonesia, 2015b), it was found that the current authorized agency with responsibility in land matters is National Land Agency (BPN), a non-ministry organization which is headed by the Ministry of Agrarian and Spatial Planning (ATR). Named also in Presidential Decree Number 17 of 2015, under the Ministry of Agrarian and Spatial Planning, the Directorate General in Agrarian Infrastructure of Ministry of ATR has the responsibility to formulate and implement the policy on cadastral survey, measurement and mapping in Indonesia. Therefore all policies and regulations related to cadastral survey, measurement and mapping including the guideline, norms, standard, procedure and evaluation are the responsibility of the Directorate General in Agrarian Infrastructure.

3.1.2. Procedure and Technology

The procedure on cadastral boundary data acquisition in Indonesia, according to *Government Ordinance Number 24 on Land Registration* (Republic of Indonesia, 1997a), consists of registration basic mapping, delineation cadastral boundary, cadastral survey and mapping and registration mapping, registered land listing, and survey letter issuance. Further explanation on provision for the implementation of cadastral boundary data acquisition procedures was derived from *Regulation of the State Minister of Agrarian Affairs/Head of National Land Agency Number 3 on Provision of Land Registration* (Republic of Indonesia, 1997b), which became the basic guideline for the implementation of land registration in Indonesia, including the cadastral survey and mapping procedure, and can be seen in the following paragraph.

– *Registration Basic Mapping*
  The activity of registration basic mapping is aimed at providing the basic map for registration. Details to be surveyed cover all or part of geographic elements, such as rivers and roads. In case the survey is conducted at the same time of parcel boundary survey, all details around the parcel such as buildings should also be recorded. The measurement and mapping activity can be carried out with terrestrial method, photogrammetric or other methods, and the output of the map can be generated

in various scale depends on the purpose as can be seen in Table 4. For cadastral purposes in Indonesia, the coordinate system used is National Transverse Mercator with wide zone of 3º or recognized as TM-3 º (see Appendix 2).

Table 4: Various output scale in registration basic mapping

Purpose	Scale
Residential	≥ 1:1.000
Agriculture	≥ 1:2.500
Plantation	1:10.000

– *Delineation on Cadastral Boundary*

To obtain the physical data for the land registration purpose, boundary markings should be planted on every corner of the parcel to be surveyed. The markings should be done by the claimant of the parcel which resulted from an agreement with the neighbours. In case there is a disagreement towards the boundaries, it should be resolved between the claimant and the neighbours, and settlement over the disputes will be recorded in Treatise Boundary Dispute Resolution. On the other hand, if the settlement could not be carried out then a temporary boundary will be recorded and any objection towards the boundary shall be filed to the court.

Initially, the boundary marking should be planted in every corner of the parcel which will be surveyed. But in case the boundaries are already represented by fixed-built up materials such as concrete walls, fences and wired fences, it is not necessary to place any markings. The materials and size for boundary markings should follow the following rules.

Table 5: Size of boundary markings for existing procedure

< 10 Ha	> 10 Ha
Metal pipe / pipe rod length ≥ 100 cm and diameter ≥ 5 cm;	Metal pipe length ≥ 1.5 m and diameter ≥ 10 cm;
Pipe contained concrete materials length ≥ 100 cm and diameter ≥ 5 cm;	Block of iron length ≥ 1.5 m and diameter ≥ 10 cm;
Iron wood/teak length ≥ 100 cm and width ≥ 7.5 cm;	Iron wood/teak length ≥ 1.5 m and width ≥ 10 cm;
Monument of brick sized ≥ 0.20 x 0.20 x 0.40 m;	Monument of brick sized ≥ 0.30 x 0.30 x 0.60 m;
Monument of concrete materials sized 0.10 x 0.50 x 0.40 m	Pipe contained concrete materials length ≥ 1.5 m and diameter 10 cm

– *Cadastral Boundary Survey and Mapping and Registration Mapping*

During the cadastral boundary survey, the land claimant and the neighbours should be present and show the boundary markings of the parcel. Cadastral survey can be carried out using terrestrial method, photogrammetric, or any other method that follows the principle of survey and mapping and thus the parcel boundary could be mapped, identified, and reconstructed. From the *Technical Instructions and Guidelines for Survey and Mapping Procedure of BPN* (National Land Agency of the Republic of Indonesia, 1997), the details of each method were given as can be seen in Table 6.

Table 6: Methods of cadastral boundary survey and mapping in Indonesia

Method	Procedure	Equipment
Terrestrial	Cadastral survey with terrestrial method for systematic and sporadic land registration is conducted in the field by determining the angles and distances of the boundary markings on a flat plane. There are 2 types of terrestrial method: offset and polar. The method of terrestrial survey to be done could be adjusted following the practical field situation and requirement of data to be recorded.	Theodolite/ ETS; EDM/ Measuring Tape; Prism; Ranging Poles; Survey Drawing Form; Survey Form; Stationery.
Photogrammetry	Cadastral survey with photogrammetry for systematic and sporadic land registration is for an open area which is easily identified. Photogrammetric product which can be used for cadastral survey are aerial photo blow up, photo map and line map. Procedure of cadastral survey with photogrammetry is by surveying the boundary in the field with terrestrial method and using the product of photogrammetry for sketch plot and record the result value of the survey to support the survey drawing from.	Photo Map with scale of 1:2.500 or 1:1.000; Measuring Tape; Needle; Survey Drawing Form; Survey Form; Stationery.
Others methods	Cadastral survey for systematic and sporadic can also be conducted with other methods using technology that could cover the accuracy of the methods above, such as satellite imagery and GPS.	

Survey drawing (see Appendix 3) is a documentation of cadastral survey with distance, angles, azimuth and sketch of the parcel and its surroundings. It will be used for land registration purposes and should be able to provide information for reconstruction in case the boundary markings on the field is no longer existing. Since it is a documentation of the field survey, it should be drawn in the survey location and not in the office.

– *Registered Land Listing*
  Parcels which have been surveyed and mapped in a registration map will be recorded into registered land list. The list file is organized for each village/sub-district (Appendix 4).

– *Survey Letter Issuance*
  For the land registration purpose, a survey letter will be published as the parcel is registered already in registration map. The letter will present the physical data of the parcel which resulted from the cadastral survey in the field (see Appendix 5). According to *Regulation of the State Minister of Agrarian Affairs/Head of National Land Agency on Delegation of Authority Regarding Land Titling and Land Registration* (Republic of Indonesia, 2013), a survey letter is signed by the Head of Survey, Measurement and Mapping Section. In case the Official Authority is unavailable for 5 days in a row and there is no Ad

Interim of Head of Survey, Measurement and Mapping during the absence, therefore the survey letter is signed by the Head of Measurement and Mapping Sub Section on behalf of the Head of Survey, Measurement and Mapping Section.

The issuance of survey letter is the last step on cadastral boundary data acquisition procedure. To give a comprehensive understanding on the existing procedure, a flow chart of existing cadastral boundary data acquisition was investigated (see Appendix 6).

3.1.3. Fees and Duration

In addition, for the provision of the cadastral survey, regulations related to the fees and duration for the implementation of the procedure was issued by the government. *Government Ordinance on Fees of Non-Tax Revenue for National Land Agency* (Republic of Indonesia, 2010a) regulated the fees for survey, measurement, and mapping is formulated as can be seen in Table 7:

Table 7: Formula to calculate fees for cadastral survey service in BPN

Area	Formula
<10 Ha	$T_u = \left(\frac{L}{500} \times HSBKu\right) + Rp. 100.000,00$
10 to 1000 Ha	$T_u = \left(\frac{L}{4000} \times HSBKu\right) + Rp. 14.000.000,00$
>1000 Ha	$T_u = \left(\frac{L}{500} \times HSBKu\right) + Rp. 134.000.000,00$

By using the formula in Table 7, we will be able to calculate the fee for each parcel (T_u) that conducted in a sporadic way. Meanwhile the fee for mass cadastral survey such as systematic way is 75% of the value computed using the similar formula. $HSBKu$ which is mentioned in Table 7 is the unit price for special fee in surveying, and the variety value of $HSBKu$ for 34 provinces is delivered in *Regulation of the State Minister of Finance on Index Rate Calculation of Non-Tax Revenue* (Republic of Indonesia, 2012) (Appendix 7).

Furthermore, the duration of cadastral survey is mentioned in the *Regulation of the State Minister of Agrarian Affairs/Head of National Land Agency on Standard for Land Service and Arrangement* (Republic of Indonesia, 2010b). The duration for cadastral survey varies on the purpose. For the boundary reconstruction of an area less than 40 Ha the maximum time to conduct the procedure is 12 days, meanwhile for an area more than 40 Ha the time to carry out the survey is 30 days. On the other hand, cadastral survey for inventory/land acquisition purpose, request in parcel determination and topography mapping is limited to be done within 18 days. These provisions regarding the duration will later be used for comparison to evaluate the output of the new approach.

3.1.4. Constraints on Existing Cadastral Boundary Approach

Although it is already stated in Government Ordinance Number 24 of 1997 that cadastral data acquisition is possible to be done with other methods beside terrestrial method (e.g. photogrammetric), the fact is that on the ground, it is still undertaken with terrestrial methods. According to United States Agency International Development (2010) both sporadic and systematic registration in Indonesia is still using typically use ground survey methods. This happened due to the limitation of base map availability: the required scale of 1:1.000 or greater for residential areas requires high-resolution imagery and this is usually not available.

Constraints related with the cadastral data acquisition method in Indonesia were also specified by Sadikin et al. (2014). The first problem is the availability limitation of high-resolution images. This is caused by the high cost, insufficient period of procurement, and cloud cover constraint. Another problem is the topography characteristic in several regions in Indonesia. Sadikin et al. (2014) mentioned that constraints of accessibility, weather and the extent of the area surveyed cause mapping by terrestrial means or direct observation to also be used in areas with characteristics of undulating topography. Ultimately, this means they remain unmapped.

Cadastral surveys in Indonesia were conducted using conventional terrestrial methods up to around 1994 where the measurement was carried out in local coordinate systems. Stated in Abidin et al. (2015), the application of local coordinate system for cadastral boundary data acquisition created problems as the parcel boundaries were plotted in a single cadastral basic map of the area, where many parcels were overlapping and sometimes gaps between parcels also existed. To overcome this problem, BPN started to use Global Positioning System (GPS) for cadastral surveying in Indonesia in from 1994 onwards.

To improve the use of GPS, since 2009, BPN has started to establish Global Navigation Satellite System Continuously Operating Reference Stations (GNSS CORS) for cadastral survey purpose. However, the typical topography and land coverage around land parcel boundaries in Indonesia will not always allow for good GPS observations directly at the parcel boundary points where significant GPS signal obstructions from buildings and trees can be frequently expected (Abidin et al., 2015). Therefore, a combination of terrestrial measurements is usually implemented to conduct the survey, e.g. use of measuring tape for dense urban environment and tied the result to control points surveyed by GPS.

Derived from Feryandi, Sabekti, Silalahi, Adnan, & Dariatna (2014), 56% of the land offices stated that the Survey and Mapping Division in Land Offices have no adequate employees and only 50% of employees have competencies and the skills required. In addition, to the human resource obstacles, the infrastructures and facilities available in the Survey and Mapping Division were also mentioned to be one of the barriers. It was also delivered by Feryandi et al., (2014) that 51% Land Offices have poor infrastructure and facilities such as inadequate equipment for cadastral survey and unavailability of ideal infrastructure working space.

3.2. UAS in Indonesia

3.2.1. Policies and Regulations

The provision on the air space of Indonesian territory is stipulated in Article 33 Clause 3 of *the Constitution of the Republic Indonesia* (Republic of Indonesia, 1945) regarding the authorization of land, water and natural resource of Indonesia and also *Aviation Law* (Republic of Indonesia, 2009). It is defined in *Aviation Law of 2009* that aircraft is any machine or tool that can fly in the atmosphere due to the lifting force of the air reaction, and not the air's response to the earth's surface. Therefore the implementation of UAS as an aircraft is also covered in *Aviation Law of 2009* and regulations which are the derivative of it.

Government as the executive board has the right and responsibility to regulate the national air space management in Indonesia and also to determine the restricted and limited air space within the region of Indonesia. Therefore to increase the aviation safety regarding the flying of UAS in Indonesia, on 12th May of 2015 the Ministry of Transportation (MoT) issued the *Regulation of the State Minister of Transportation Number 90 on Control for the Operation of Unmanned Aerial Vehicle* (Republic of Indonesia, 2015c) which includes the rules to control operation of UAS in Indonesia.

The *Regulation of the State Minister of Transportation Number 90/2015* specified the requirements, restrictions and licensing in operating the UAS in Indonesian air space service. The definition of UAS is mentioned in the decree as any flying machine that functions by remote control operated by pilot or able to control itself using the laws of aerodynamics. Also noted in the decree is the general provision on the system operation, the UAS can be operated by an individual party, group of people, organization, and government institution.

3.2.2. Constraints on UAS Application in Indonesia

According to the *Regulation of the State Minister of Transportation Number 90/2015* there are some provisions to be followed in operating UAS in Indonesian air space that can be sum up in the following points:

- *Restriction on flying UAS in some areas*
  There are some areas that is restricted for UAS operation: prohibited area, restricted area, flight operation safety area, controlled airspace and uncontrolled airspace at an altitude of more than 500 feet ≈ 150 meter. The restricted areas included are more likely exists to avoid the disturbance towards the operation of manned-flight (commercial and military).

- *Special provision*
  On special occasion related with the government interests, flying UAS on the uncontrolled airspace above 500 feet or 150 meter is allowed with the permission and coordination with the flight navigation unit which is responsible for the operation. The request of flight license must be submitted to the Ministry of Transport at least 14 working days prior to the operation of the UAS and the change should also be informed less than 7 days before the execution. Information submitted should include the UAS: operator's name and contact, airborne system specification, ground system specification, aim and objective of the operation, flight plan, emergency procedure, insurance document, remote control operation, pilot's competency and experience. The flight plan should also describe the airborne identification, the flight rules and flight type, equipment, departing points, estimated operation time, cruising speed, cruising level, flight route, arrival points and total estimated elapsed time, alternative points for departing/arrival, battery lifespan, cruising range of operation and maneuvering operation area.

- *Restriction operation based on equipment on board*
  UAS with camera on board are not allowed to fly more than 500 meter from the border of prohibited area and restricted area. Operation of UAS for photography, film and mapping purposes should include the license or cover letter from the institution and local government where the operation will be located.

- *Penalty*
  Penalty due to the violations committed will be given in line with the rules of *Aviation Law of 2009*.

3.2.3. Development of UAS application in Indonesia

The use of UAS in Indonesia can be categorized into 2 categories: personal and professional interest. Both the personal interest, such as hobby, and professional interest, which are more likely related to work or research towards the UAS, are increasingly developed in Indonesia. Furthermore, in UAS operation for personal interest or hobby, a community named Indonesian Drone Pilot Association is officially incorporated in February 2015 (Indonesian Drone Pilot Association, 2015) to facilitate the activities for drone owners and also to grant license for the drone operators.

Initially, the UAS application in Indonesia started in 1995 for a military operation purpose (Gatra News, 2014) and has been progressing to other purposes such as surveillance of national park (Antara Sumbar, 2015) and environment (Rappler, 2015), traffic and security (Deutsche Welle, 2015), monitoring of mining

(Berita Satu, 2014) and taxation (Bloomberg Business, 2015), and also deterioration and preservation world heritage sites (Suwardhi, Menna, Remondino, Hanke, & Akmalia, 2015).

In line with the application of UAS, researches involved in developing the implementation of UAS in Indonesia were also done. A study in the potential of UAS for supporting precision agriculture was conducted by C. A. Rokhmana (2015) which resulted in an ortho-photo and digital elevation model (3D point cloud) with accuracy of up to 2 pixel error for horizontal position and 5 pixel error for vertical. Other works using UAS in Indonesia were also carried out on potential peat fire detection (Teguh, Honma, Usop, Shin, & Igarashi, 2012), telecommunication network coverage area expansion in disaster area (Alvissalim et al., 2012), irrigation monitoring (Waskitho, 2015), rapid mapping activities (Tampubolon & Reinhardt, 2015), restoration of logged humid tropical forests (Harrison & Swinfield, 2015), and counter-mapping land grabs (Radjawali & Pye, 2015).

3.3. Summary of Chapter 3 – Requirements

Requirements to design a new approach for cadastral data acquisition are covering two parts: Indonesian cadastral boundary needs and UAS regulations in Indonesia. Understanding the two topics is aimed to introduce the existing "status" of cadastral boundary and the regulation of UAS in Indonesia. The first review – cadastral boundary survey in Indonesia – informs that the responsibility to formulate and implement the cadastral survey belongs to BPN, and the importance of registering the whole land in the country is now one of the policy priority of Indonesian government. The main activities of cadastral boundary data acquisition in Indonesia according to *Government Ordinance Number 24* (Republic of Indonesia, 1997a) are registration basic mapping, delineation cadastral boundary, cadastral boundary survey and mapping and registration mapping, registered land listing, and survey letter issuance.

Although the fact on the ground reveals that cadastral survey is still using the ground survey method, the regulation already includes the possibility of using photo map for cadastral survey. But due to limitation of base map availability to fulfil the required scale for cadastral mapping, the use of photo map is unable to be undertaken.

As a result for the UAS regulation review, it is known that a new regulation which explicitly stipulate the UAS operation in Indonesia was issued on 12th May 2015. This authorizes the Ministry of Transport to manage the UAS in Indonesia, including permit issuance for the operation. It defines the restricted areas to operate UAS such as prohibited area, flight operation area, and etc. Another highlighted provision from the regulation is the fact that, UAS operation in altitude below 150 meters does not require for registration. The activities of cadastral boundary mentioned above will be included to the next stage – designing UAS based image approach. Rules on UAS operation will also be taken into consideration to design the flight plan, given the fact that there is a limit altitude and area restriction for UAS operation.

4. DESIGN: UAS DRIVEN CADASTRAL BOUNDARY DATA ACQUISITION IN INDONESIA

The process of designing and testing a UAS based approach consists of sequential activities that were aimed at answering sub objective 2. In this section a description on how the study attempts to address the formulated research questions for sub objective 2 is given. It includes the study area description and also details of methods and techniques used in the research.

4.1. Designing a UAS Based Image for Cadastral Boundary Data Acquisition in Indonesia

To support the design, articles on UAS photogrammetric and boundary definition procedures were reviewed and elaborated upon. In this vein, the procedure was designed by adapting and developing the current procedure of *Orthophoto Production Using Digital Aerial Imagery* (Udin & Ahmad, 2014) and *Participatory Adjudication Integrated LARSI* (Jing, 2011) (see Appendix 18). Considering the requirement of the existing procedure of cadastral boundary data acquisition in Indonesia, a flowchart of *UAS Based Image Approach Design* was drawn using *Enterprise Architect* (Figure 9). This flowchart also included the essential technology infrastructure involved in the new procedure.

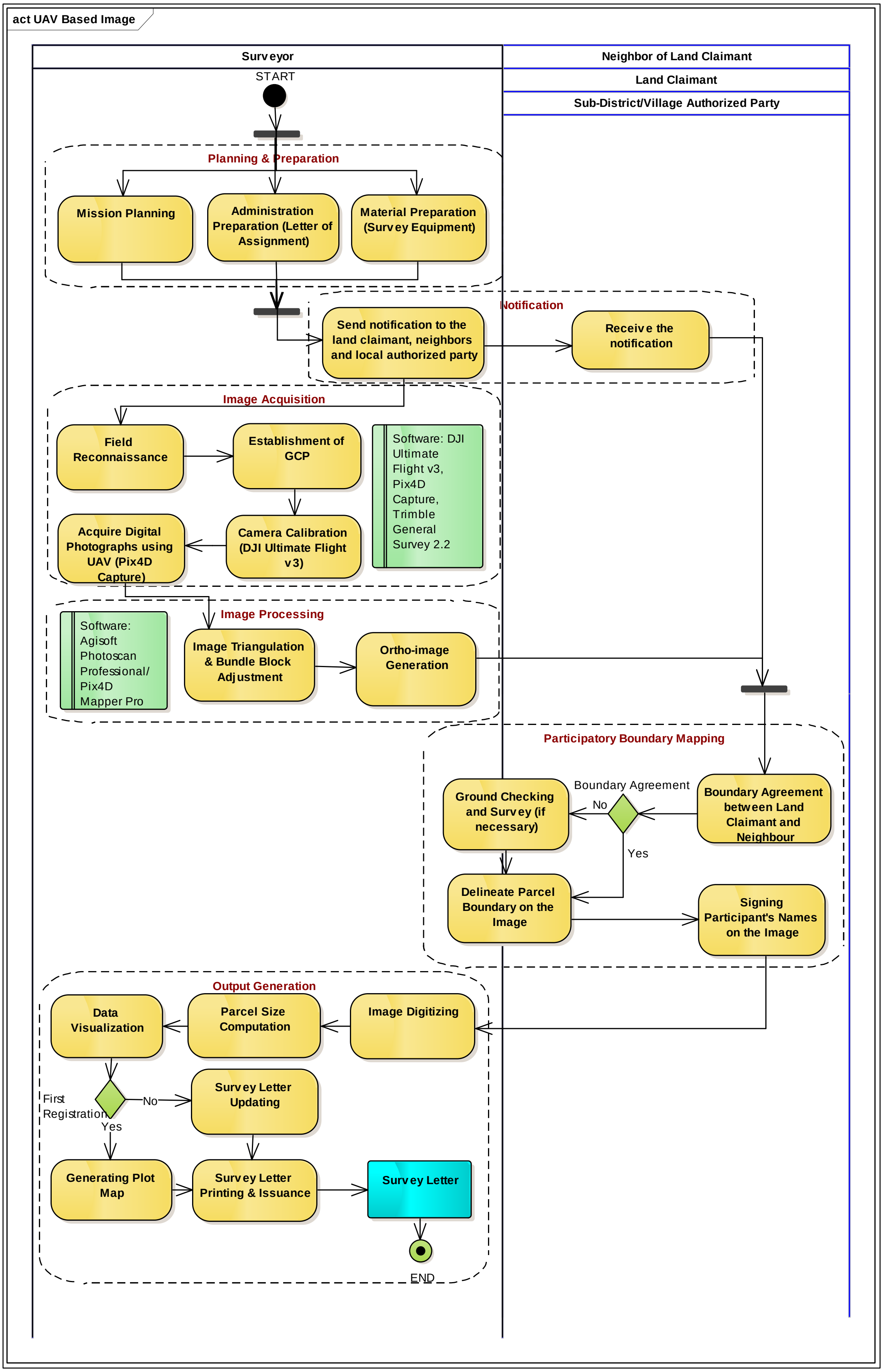

Figure 9: Flowchart for cadastral boundary definition using UAS based image approach

4.2. Testing UAS Based Image for Cadastral Boundary Data Acquisition in Indonesia

4.2.1. Study Area

The study area of the research is in the District of Sumbawa Besar in Nusa Tenggara Barat (NTB), where on July 2015, a project of systematic land registration was held by *Kanwil BPN NTB* in Lunyuk Ode Village and covered ±200 Ha of the village. Lunyuk Ode Village lies at the southernmost part of Sumbawa Island, an island which is part of NTB Province. It is located in 8.97023ºS and 117.21587ºE with approximated area of 4706 Ha (Government of Sumbawa District, 2015). Lunyuk Ode is the capital of Lunyuk Sub District with 3025 populations and currently the registered land in Lunyuk Ode is 918 parcels with ownership right of an area around 575 Ha.

Considering the problem of the research, a study area was chosen based on the following criteria: low number of registered land, non-conflict area, and not an "*adat*" land. According to the data given by the authorized staff in Center of Data and Information (Pusdatin) of ATR Ministry, only 12.22 % area in Lunyuk Village were registered, hence testing an approach to support a fast, cheap and appropriately accurate in this location might increase the amount of registered land. It is not possible to proceed with the registration of conflicted land and "*adat*" land are not determined to be registered formally in Indonesia. These two criteria are duly fulfilled by Lunyuk Village. Therefore, this study area is not only chosen based on the availability of data, but also because the location meets the criteria given.

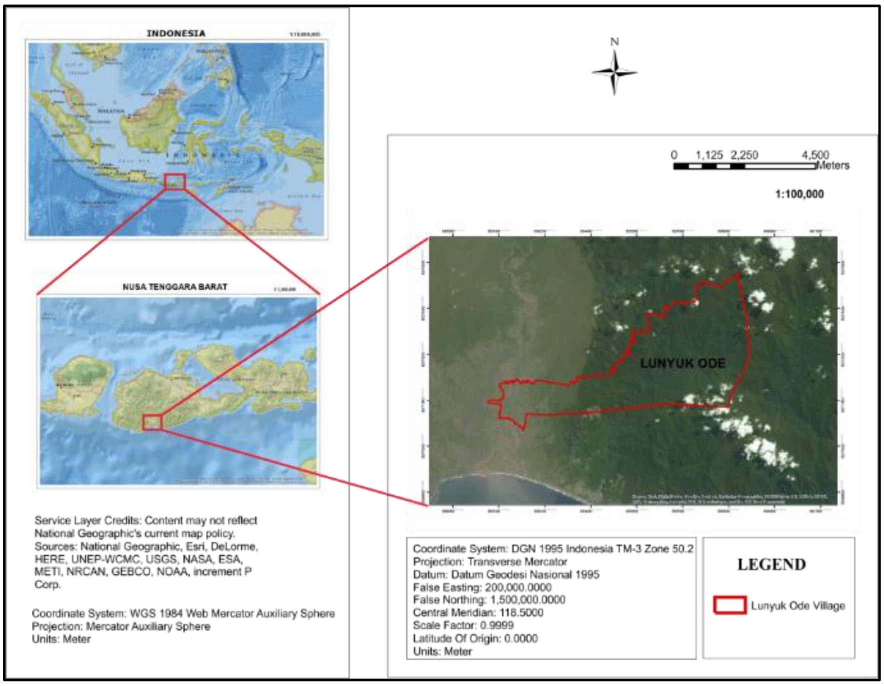

Figure 10: Study area

4.2.2. Applying the New Procedure

4.2.2.1. Preparation

– *Fieldwork Planning and Administrative Preparation*

Due to the involvement of government institutions, private companies, and community groups, a comprehensive preparation was carried out before going to the field for data collection. Regarding the ethical consideration, intensive contact with the person from each party was done to find out the hierarchy of the bureaucracy and local culture with respect to the anticipated procedures during fieldwork. As supporting documents, cover letters (in Bahasa) from ITC informing the aim of the fieldwork and thesis proposals (in Bahasa) were also prepared.

Considering the ethical issues, meeting with the authorized parties (Head Village and Sub-District Head) of the fieldwork location was also carried out. The agenda of the meeting was to inform stakeholders about the research and ask for permission to work in their area. During that occasion also the author informed about the intention of testing the UAS based image procedure which might require the support of local people as the land claimant. As well as the behavior ethics consideration, some ethics were also noted during the interview and participatory boundary mapping. These ethics were remarked from Rambaldi et al. (2006) (appendix 17):

1. Be open and honest;
2. Informed Consent;
3. Be certain and clear about the purpose;
4. Avoid raising false expectations;
5. Invest time and resources in building trust;
6. Avoid exposing people to danger;
7. Be flexible and don't rush regarding to the process;
8. Be considerate in taking people's time;
9. Be careful in avoiding causing tensions or violence in a community;
10. Facilitate the respondent.

– *Instrument, Software and Datasets*

Regarding the permission and instrument needed, meeting and discussion with government institution involved (*Kanwil BPN NTB* and *Kantah* Sumbawa Besar) and private company became the first agenda of the fieldwork activity. One unit of UAS and a drone pilot from a private company were settled from the meeting with the private company. Support of GNSS RTK and two licensed surveyors were also given by *Kanwil BPN NTB*. As a comparison, later also, datasets of previous but recent land adjudication projects using terrestrial methods in Lunyuk Ode were also shared by *Kanwil BPN NTB* and *Kantah* Sumbawa Besar. Another thing prepared was the software to process data, both in the field and post field. A list of the instruments, software and materials prepared are compiled in Table 8.

Table 8: Instrument, software and datasets of the research

Category	No.	Name	Purpose	Source
a. Instrument	1.	*DJI Phantom 3 Advanced*	Image acquisition	Private Company
	2.	*Trimble GNSS Receiver NetR9* (Base and Rover)	GCP survey	BPN
	3.	Laptop/computer desktop (Intel Core i7, RAM 8 Gb)	Data processing	ITC
	4.	Smartphone	Image acquisition	Private company
	5.	Markings for 26 GCPs	GCP signalization	ITC
b. Software	1.	*ArcGIS 10.3*	Project planning and processing	ITC

Category	No.	Name	Purpose	Source
	2.	*DJI Ultimate Flight v3*	Calibration	Play Store (Purchased)
	3.	*Pix4D Capture Mapper*	Image acquisition	Play Store (Free)
	4.	*Agisoft Photoscan Professional 64 Bit*	Image processing (in the field)	http://www.agisoft.com/
	5.	*Pix4D Mapper Pro*	Image processing (post field)	https://pix4d.com/products/ and ITC
	6.	*Trimble General Survey 2.2*	GCP generation	BPN
	7.	E*nterprise Architect 11*	Flowchart design	ITC
	8.	*TextSTAT -2.9c*	Result visualization	ITC
	9.	*Microsoft Office 2010*	Analysis and reporting	ITC
c. Dataset	1.	Registered Parcel in Lunyuk Ode (shapefile)	Analysis	BPN
	2.	Images of the study area, date acquisition 26 May 2011 (jpeg)	Pre-survey: GCP distribution	Google Earth
d. Personnel	1.	Pilot/UAS Operator	Image acquisition	Private Company
	2.	Licensed Surveyor	Survey GCP	BPN

4.2.2.2. Field Data Collection

Field data collection is a sequence of activities meant to test UAS Based Image Approach which was developed in the previous section.

– *Pre-survey*

For the preparation of the image acquisition and GCP measurement, a reconnaissance visit to get an overview of the location was conducted. Major attention was paid to essentials element which might affect the image acquisition procedure and GCP measurement such as the land use, land cover and weather. After investigating the location which mostly consists of the crops field, some part of the area which is residential and some other part which is crops field were decided to be the main area of interest for the research. Regarding the weather, Indonesia only has two seasons: rain and dry season, and by the time of the fieldwork which was on October 2015, it was still dry season. The weather was sunny and the wind was not strong during the day time. From the suggestion of the local people, the perfect time to capture the images started at 8.00 AM in the morning until afternoon before 5.00 PM, because it would get darker and the wind would become stronger in the afternoon after 5.00 PM. After seeing the location, the location of fieldwork was relatively a flat terrain. The crops were just harvested so the crops fields were bare, only some cattle and horses were there. The neighbourhood of the residential area was also not crowded during the day.

Another pre-survey activity was creating the GCP markings and set them in the field. The GCP distribution was created using a dummy-image from *Google Earth*. Using this image, a description on where the location of the GCP will be located was able to create. In total there were 25 points planned to be collected. The GCP markings were done by using mix of nature-mark and man-made marks. The man-made markings used a red-crossed marking made of plastic (to be planted in the crops field) and white painted markings (for roads), as can be seen in Figure 11. The colour was different to make it contrast, white colour for the road since the road was black and red colour for the crops field since the field was dusty brown.

Figure 11: GCP markings

- *Image Acquisition and GCP measurement*

  A trial flight was carried out to test the UAS unit, *DJI Phantom 3 Advanced* (see Figure 12), a rotor unit of drone with a perspective lens camera attached in the platform. The camera specifications for the image acquisition can be seen in Table 9. Some software to operate the flight in the field was also tested. The software used to conduct the flight was: *DJI Ultimate* (calibration) and *Pix4Dmapper Capture* (capturing mission). *DJI Ultimate* was used to do the calibration of the UAS unit in the field before the image acquisition and *Pix4Dmapper Capture* was used to automatically acquiring images.

Table 9: Specifications of *DJI Phantom 3 Advanced* for the research

Camera Model	Sony EXMOR FC300S
Focal Length	3.68 mm
Pixel Size	1.579 µm
Average Ground Sampling Distance (GSD)	2.99 cm
Image Size	4000 x 3000 mm
Sensor Size	6.317 x 4.738 mm
Image Coordinate System	WGS 84 Zone 50 S

Figure 12: Platform (DJI Phantom 3 Advanced) used for the research

After the connection between the UAS and the remote as the ground station was set up, a brief setting for the flight parameter was established, such as 70 m height; high overlap (90% frontal overlap and 60% side overlap); and size of the area to be captured. The trial flight was done for half of the day–3 times–which was excluded from the final data. In total, to complete the final data, the UAS was flown 7 times (mission 1 to mission 7). The area of the field was divided into 4 blocks. Each block was captured in one mission, so there were 4 blocks (372 images) to capture the whole area of fieldwork (± 32 ha). But to make a better result in the residential area (buildings), 3 more blocks were added, therefore in total 7 flights (532 images) were executed. The UAS flew for around 7 minutes for each flight, but to avoid the chance of the falling due to low battery, every time the UAS was flown, it was taken back to the base to charge the battery.

Figure 13: UAS calibration and flying

The GCP measurement was conducted using GNSS RTK. A set of RTK–one base and one receiver–were used to get the coordinate of control points. In total, 26 points, including one base were collected during this activity. The activity was done in less than an hour for an area of 32 Ha. It started by setting up the base, then while the first surveyor was posting in the base, the other surveyor went to measure the pre-marked GCPs by placing the receiver pole in the middle of the markings one by one. An unexpected experience occurred when suddenly in the middle of the measurement, the base did not send the correction because it went off due to the battery discharged. The surveyor who was waiting on the base borrowed an external power (accumulator) from the nearest car to complete the measurement.

Figure 14: GNSS base and receiver for RTK in GCP measurement

- *Image Processing*

  As part of the testing procedure, the image processing was also done in the field. The processing was done according to the plan by using trial version of *Agisoft Photoscan* (from now on AP) which can be downloaded from *Agisoft* website. AP was used for practical reasons, since it provided a trial version of the stand-alone photogrammetric application that could generate images in the field instantly.

  After some trial and error, including a software crash caused by the trial version instability, the processing was completed inside two days. Furthermore, after trying to process itself using the processing outline found during the trial and errors, it took around 4 hours to process the images (372 images). The images which were processed in this activity came from only 4 missions (372 images) which already cover the whole fieldwork area, and excluded the other 160 images.

  After successfully generating the output imagery (Appendix 8), the next step was to plot or print out the image. The image was scaled down to 1:500, and due to the limited source of equipment, the image could not be printed out using a plotter machine. Therefore a manual mosaicking was carried out by printing out the image one by one using F4 paper, and glued one by one to produce the 1:500 scaled image (Appendix 9).

Figure 15: Mosaicking activity and output of image processing activity

- *Participatory Boundary Mapping*

  This activity was aimed to test whether the activity of participatory mapping to define the boundary of the parcel can be implemented or not. As what mentioned earlier, during the pre-survey activity, the authorized party was also informed that one of the activities later would be a participatory boundary mapping that would require people from the village. We asked the head of the village to gather people in the village office on Thursday, 15th October 2015. The available respondents with adjacent neighbours on that day were 5 participants, thus the participatory boundary mapping was done with participation of 5 people, which represented the owner of crops field and residential area, and also with the presence of the head of the village to witness the procedure.

  The participants pointed out the boundary of their land directly in the printed image, and by the agreement of neighbours the points were marked in the image. These marking points indicated the boundary of the parcels which then also signed by also putting the land owner's name inside the boundaries. After the boundary definition, the next step was digitizing the points to get the boundary. The plan was to have the whole boundary definition in the initial gathering place which was the village office, but due to the boundary disagreement in one of the parcel, the land owner/claimant and the surveyor went to the location, checked the boundary and did an extra measurement using measuring tape. The disagreement was caused by the coverage block by the vegetation to one of the boundary corner shown by the land owner. Beside the difficulty to delineate due to the vegetation cover, some facts during the event were also noted. During the boundary delineation there was a respondent who mistakenly showed his parcel boundary in the image which then was corrected by the adjacent neighbour that was present in the event. Another thing is the fact that the respondents always started by looking for landmarks or locations in the image that they are familiar with – to help them find their parcels.

Figure 16: Participatory mapping and interview activity

– *Interview*

After the field data acquisition was done, the last activity of data collection was the interview. It involved 2 types of respondents: land owners to get the information about their view about the new procedure compare to the existing one and the surveyors to get the information about the existing procedure. The interviews were conducted by recording the conversation using a recorder device by the consent of the interviewee.

4.2.2.3. Output Datasets

From the field data collection, 5 datasets were compiled as can be seen in Table 10. These datasets will be discussed in Chapter 5 and 6.

Table 10 : Lists of datasets derived from field data collection

No.	Data	Type
1.	Quality Report	Digital (.pdf)
2.	Parcel Boundary	Digital (.shp)
3.	Interview Transcripts	Digital (.docx)
4.	List of Cost and Duration	Digital (.xlsx)
5.	Secondary Data from Existing Approach	
	- Parcel Boundary	Digital (.shp)
	- Cost Report	Hardcopy

– *Quality report*

In total 532 images from 7 missions were re-processed using *Pix4DMapper*. The purpose of doing reprocessing was to get a better overview over the image accuracy since *Pix4D Mapper* functions well in providing information of the accuracy of the distributed GCPs. *Pix4D Mapper* is a software which specifically designed for UAS application. It was intended to use *Pix4D Mapper* from the beginning of the project. But due to the license issues (free version of *Pix4D Mapper* only available online), it was then decided to use AP to proceed the images on the field. From geo-referencing in initial processing using *Pix4D Mapper*, 21 points (18 GCPs and 3 CPs) were used to produce the ortho-photo (Appendix 10) and a quality report (Appendix 11) was generated. Thus, analysis on the report to evaluate the quality of the ortho-photo could be done. The quality report showed that the accuracy of the GCPs are 3.4 cm for X and 2.6 cm for Y.

– *Parcel Boundary*

A dataset of the parcel boundary was compiled as the output of the participatory boundary mapping activity. Five parcels in total were digitized and the area size for each parcel was generated in square meter using *ArcGIS 10.3*.

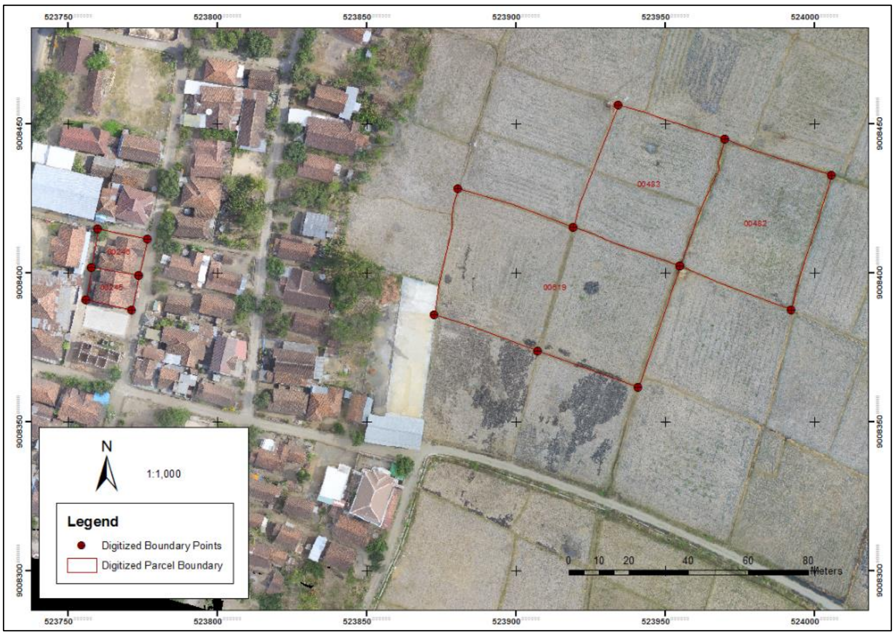

Figure 17: Digitized parcel boundaries from UAS based image approach

– *Interview Transcripts*

Elements for evaluation incorporated into the interview session, and the recorded interview was transcribed using *Ms. Word.* (Appendix 12).

– *List of Cost and Duration*

List of cost and duration of the UAS based image approach were developed from the author's experience and notes during the data collection in the field, and also from the national document of Indonesia about general fee standards.

– *Comparative Secondary Data from Existing Approach*

Source: *Kanwil BPN NTB* and *Kantah* Sumbawa Besar. Parcel boundary (Appendix 13) was measured in the field using RTK and ETS and processed using *AutoCad* software and projected in local coordinate system TM-3. The budgeting report (Appendix 14) was derived from the budget implementation form of the same project.

4.3. Summary of Chapter 4 – Designing

With the requirements gathered from the Chapter 3, sequential activities designed for UAS based image approach are elaborated in this chapter. There are 6 main group activities inside the new approach: planning and preparation, notification, image acquisition, image processing, participation boundary mapping and output generation. The major difference with the existing procedure lies on the demarcation boundary and measurement phase. The new approach does not require the boundary demarcation on the ground by the land claimant, and the boundary delineation is conducted with the participatory mapping – engaging the land claimant, adjacent neighbours and authorized party from the village. Another essential difference is the presence of UAS image generation inside the approach. To assess the result, an evaluation towards the generated output from the testing stage will be carried out in Chapter 5.

5. EVALUATION

5.1. Elements of Evaluation

Evaluation is the last stage in sequence of activities conducted to answer the sub objectives of this research. The literature review revealed elements of data quality which are considered to be relevant for the evaluation of UAS based image approach. There were two documents reviewed which included 12 elements (see Appendix 19). First document, *ISO 19157:2013* (International Standards Organization, 2013) has 5 criteria of spatial data quality, while the second document, *Fit-for-Purpose Land Administration* by (Enemark et al., 2014) mentioned 7 fit-for-purpose elements. In the end, the 12 combined elements were narrowed down to only 7 fit-for-purpose elements. This decision was taken since the elements of fit-for-purpose were considered more relevant, if not contemporary, for the evaluation – whilst the spatial data quality criteria only recognize the output for the quality assessment and not the whole procedure.

To assess the UAS based approach, a comparative study of two different methods based on fit-for-purpose elements, which include the terms of evaluation in sub objective 3 of this research, was conducted. Considering the problem justification, an adjustment to the elements of fit-for-purpose was made with the relevancy of 3 criteria: cost, duration (time), and spatial accuracy achieved of the procedure.

In the end there were 4 elements from the fit-for-purpose criteria listed as the evaluation criteria for the UAS based image approach in this research. The first element was "participatory" or measuring the level of "participation" that was carried out in each approach. The second element "attainable" is aimed to assess the duration of the procedure. "Affordable" as the third element from fit-for-purpose seeks to evaluate the cost component to operate each method. The last element focused on the "reliability" aspect of the information acquired and shared – and considered to include the spatial accuracy element. Each of the elements can be evaluated from the data derived from the field studies.

Figure 18: Elements of evaluation

5.1.1. Participatory

The developed UAS based data collection approach also included the element of "participatory", as perceived by landowners, and consequently its evaluation is entirely necessary. The Method of evaluation was done using the interview transcripts that were conducted: 6 respondents were the key informants. All of the informants interviewed were present during the participatory boundary mapping activity conducted during field data collection.

A number of questions related to the respondents' experience on practicing the UAS based image approach were asked. The focus was on recording the perceived involvement of participants during the boundary mapping activity, however, other aspects such as the impression of the approach in general and trust in relation to the output given were also questioned.

When being asked about the approach in general, the respondents gave a variety of answers as can be presented in Figure 19. The terms "sophisticated" and "good" appeared 4 times for each to describe the UAS based image approach. On the other hand, questions directed at understanding stakeholders' ability to recognize their own parcel boundary (Appendix 12 Question 1 and 2) gave the result of homogenous answers: they can recognize their own parcel easily.

Figure 19: General opinion on UAS based image approach (generated in www.wordle.net)

Regarding the accuracy of the output, the respondents were questioned on their trust about the output given. For comparison, the questions were asked on 2 different approaches, the UAS based image approach and the existing one using the terrestrial. The result in Table 11 shows that 5 out of 6 respondents were very convinced and 1 respondent were convinced towards the UAS based image approach, meanwhile for the existing approach it informed that 2 respondents were very convinced and the rest 4 were convinced.

Table 11: Degree of trust towards the approach

Method	Degree of Trust				
	1	2	3	4	5
	Not Convincing	Less Convincing	Quite Convincing	Convincing	Very Convincing
UAS Based Image Approach	-	-	-	1	5
Existing Approach (Terrestrial)	-	-	-	4	2

In terms of perceived involvement, the respondents were also asked to respond on the degree of impression they perceived over 2 different approaches. Answers given by the respondents (see Table 12) delivered that 3 out of 6 perceived they were very involved and the other 3 felt involved in UAS based image approach, meanwhile towards the existing approach only 1 respondent said he/she was very involved and the other 5 felt involved.

Table 12: Degree of involvement towards 2 different approach

Method	Degree of Involvement				
	1	2	3	4	5
	Not Involved	Less Involved	Quite Involved	Involved	Very Involved
UAS Based Image Approach	0	0	0	3	3
Existing Approach (Terrestrial)	0	0	0	5	1

5.1.2. Duration and cost

To evaluate the duration and cost, the record of duration and cost of the UAS based image approach was taken from field data collection. As a comparison, the duration and cost from existing approach was also collected from the documentation and interview transcripts with the staffs and licensed surveyors in BPN.

Duration

The duration from the existing approach is derived from the interview acquired with the licensed surveyor and staff in *Kanwil BPN NTB*. Moreover, the duration for the UAS based image approach is taken from the record noted by the author during field data collection which was verified by the licensed surveyor - with whom the author conducted the field data collection with.

The activities included in the duration calculation are sourced from the activities of parcel boundary surveying and measurement in Indonesia which are categorized into 4 main activities: registration basic mapping, delineation cadastral boundary, cadastral survey and mapping and registration mapping, and registered land listing and survey letter issuance. Those activities were broken down into a detailed procedure of UAS based imagery approaches, as described in Figure 9, and the duration of each activity is given – as can be seen in Table 13. Activity Number 2, notification, is noted as non-applicable because the activity is informing the stakeholders of the activity for the boundary delineation event, therefore its duration is considered to be included already in the preparation activity.

Table 13: Duration per activity in UAS based image approach

No	Activity	Duration		Unit of Measurement	
1	Planning and Preparation – Mission Planning – Administration Preparation – Material Preparation	30	min	1	project
2	Notification		N.A.		
3	Image Acquisition – Field Reconnaissance, Pre-marking and GCP Survey – Establishment of GCP – Camera Calibration – Acquire Digital Photographs using UAS	150	min	32	ha
4	Image Processing – Image Triangulation & Bundle Block Adjustment – Ortho-image Generation	480	min	532	images
5	Participatory Boundary Mapping – Boundary Agreement – Delineate Parcel Boundary on the Image – Ground Checking and Measurement – Signing Participant's Names on the Image	30	min	5	parcels
6	Output Generation – Image Digitizing – Parcel Size Computation – Data Visualization	60	min	5	parcels

No	Activity	Duration	Unit of Measurement
	– Survey Letter Updating – Generating Plot Map – Survey Letter Printing & Issuance		
	TOTAL	720 min	5 parcels

On the other hand, duration for the existing approach is known to be varied. From the Standard for Service and Regulation of Land in Indonesia (Republic of Indonesia, 2010b), the duration for surveying each parcel boundary is between 18 to 30 days, depending on the purpose and size of the area. According to the surveyor of BPN itself, the duration of the measurement is affected by several factors as explained below:

– *Sporadic vs Systematic*
  Exclude the processing time, for daily/routine/sporadic survey per day, in total 5 parcels can be measured in the field, and for project/systematic survey, per day for an area less than 600 m^2 ideally 10 parcels can be surveyed.

– *Delimitation Contradictory*
  One of the principles as a requirement for the boundary survey is the fulfilment of delimitation contradictory, where the boundary agreement is made by the land claimant and the adjacent neighbours, and witnessed by the local government officials. In case of the inability to fulfil the principle, a delay might be held and prediction on the time delay cannot be made.

  "Waiting for the land claimant or the land owner to show their boundary is taking the longest, since we do not know the boundary, thus we do not know which one to be surveyed (personal communication, Muhammad Zarnuji, Staff in Survey, Measurement and Mapping Division in *Kanwil BPN NTB*, interview 16-Oct-2015)."

– *Shape, Size and Location of the Parcel*
  Surveying the boundary in the field might be the longest duration from the overall procedure due to the size and shape complexity of the parcel. In some cases such as the location of the area is in a remote area and the land coverage is dense, it might take more time to survey the parcel.

– *Other Factors: Overlapping Parcels, Unavailability of Base Map, Power Cut*
  During data processing, the mapping might take longer time in case the surveyed parcel indicates an overlap with the existing parcels, thus the procedure should be delayed. Another thing which also affects the delay, is the unavailability of a base map of the location and the power cut which happen quite often.

In addition, the duration for boundary survey using the existing procedure is given in Table 14. The list of activities is derived from the existing procedure with terrestrial measurement using measuring tape/ETS/GNSS RTK (Appendix 6).

Table 14: Duration from the existing procedure with terrestrial survey per parcel

No	Activity	Duration	
1	Notification – Boundary Agreement Between Land Claimant and Neighbours – Boundary Demarcation (Monumenting Boundary Markers)	360	min
2	Planning and Preparation – Base Map Preparation – Administration preparation – Materials (Equipment) Preparation	270	min
3	Parcel Boundary Survey and Measurement – Boundary Markers Checking – On the Spot Boundary Agreement (if not available) – Boundary Measurement (Measuring Tape/ETS/GNSS) – Boundary Sketching in Measurement Drawing	180	min
4	Processing – Data Processing – Data Visualization	60	min
5	Output generation – Survey Letter Updating – Generating Plot Map (for first registration) – Survey Letter Printing	40	min
	TOTAL	910	min

Cost

In terms of running the systematic approach, a guideline of estimating the cost for maintaining and updating the Land Administration System (LAS) was given by (Land Equity International, 2015). This guideline includes activities counted into annual major costs to maintain/upgrade LAS according to CoFLAS such as cost of office rent, CORS operating costs, cost of HRSI, software maintenance/upgrades, survey equipment maintenance, internet connection, ITC equipment maintenance, desktop support, and etc.

However, the whole guideline could not be followed since the implementation of CoFLAS itself is meant for the implementation of LAS, whilst the cost for the approach discussed in this research is covering the implementation of cadastral surveying part only. Therefore, the activities of cadastral survey and mapping from CoFLAS alone will be adapted here to estimate the implementation cost for the UAS based image approach. Table 15 represents the activities cost in Indonesian Rupiah (IDR) for the UAS based imagery approach and existing approach (Table 15). Detailed breakdowns for the cost element can be seen in Appendix 20. The routine/recurrent running costs for cadastral survey and mapping activity is broken down into the categories as listed.

Table 15: Cost comparison of two different approach per parcel

No.	Routine Operational/Recurrent Costs	Existing Approach	UAS Based Image Approach
1	Staff salaries (including social costs)	IDR 2,460,000	IDR 328,000
2	Staff allowances (i.e. per diem, housing)		
3	Purchase of capital equipment (i.e. IT software, hardware, survey equipment)	IDR 525,000	IDR 529,000
4	Occupation expenses (i.e. building rents, utilities, etc.)	N.A.	N.A.
5	Contract service	N.A.	N.A.
6	Repairs and maintenance	N.A.	N.A.
7	Vehicles and vehicle operation expenses	IDR 279,000	IDR 221,200
8	Materials and consumables		
	Boundary markers	IDR 300,000	0
	Total Cost per Parcel	IDR 3,564,000 *(≈USD 264)*	IDR 1,078,200 *(≈USD 80)*

In general, the total cost of a project divided by the numbers of parcels surveyed can give the information on how much it cost to survey one parcel. But for reasons such as the non-existence of occupation expenses, contract service, and also repairs and maintenance, only staff salaries, equipment rent, and transportation and materials consumables categories that will be taken into account in this calculation. Another highlighted information for the estimation calculation is that the existing approach was a project arranged by BPN in 2015 to register in total 2500 parcels, meanwhile the UAS based image approach is the testing approach in the research which successfully captured 5 parcels during the fieldwork data collection. Therefore the number given in Table 15 came from the number of the total project divided by the numbers of parcels surveyed. Details breakdown of the cost calculation is given in Appendix 20.

The cost value given for the existing approach was derived from the project document. On the other hand, the cost for UAS based image approach was using the *Standard Guidelines for Cost of the Survey Measurement in Indonesia* (Indonesian Corporate Association of Geospatial Information Survey and Mapping, 2014), *General Fee Standards of 2015* (Republic of Indonesia, 2014), and also the experiences record noted by the author during field data collection. The existing approach is a project which was fully funded by the government, although in the field it showed that there was an extra charge/fee should be paid by the land claimant for each parcel to be registered. This fee was an organized fee collected by the land claimant involved in the project to cover the expense needed for the survey and measurement purpose such as the cost of the boundary markers monumenting.

5.1.3. Spatial Accuracy Achieved

Spatial accuracy is defined as the closeness of a location to its true location (Lilburne & Benwell, 2000). A similar term was mentioned in *ISO 19157 2013* to define the spatial accuracy as positional accuracy, the accuracy of the position of features within a spatial reference system. As one of the element of data quality, positional accuracy from the dataset acquired in this research can be categorized into 2: accuracy of the UAS image and accuracy of the parcel boundary resulted from UAS based image approach.

Accuracy of UAS image

When we come to talk about accuracy of imageries map, the values of the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points (RMSE) can be used to estimate positional accuracy (Federal Geographic Data Committee, 1998). In this case, the RMSE of in total 21 distributed points (18 GCPs and 4 CPs, see Appendix 15) were processed to get the RMSE of the overall project measurement. The result of the RMSE generated using *Pix4D Mapper* is presented in Table 16.

Table 16: Accuracy of the ortho-photo produced in centimeter

	GCP			CP		
	X	Y	Z	X	Y	Z
Mean	-0.065	0.013	-0.053	-0.124	0.931	2.735
Sigma	2.417	1.908	1.439	3.460	2.405	7.762
RMSE	2.418	1.908	1.440	3.462	2.579	8.229

Accuracy of the Parcel Boundary from the UAS Based Image Approach

Through the digitizing procedure, using the manually delineated boundary map, from the participatory mapping activity as the reference, a map with parcel boundary was then generated as a dataset. An accuracy assessment towards this dataset is performed by calculating the RMSE of the difference of the parcel from the digitizing procedure (UAS based image approach) and the direct measurement in the field (existing approach).

Based on *Indonesian Government Ordinance No. 24/1997*, the boundary measurement is conducted by surveying the boundaries shown by the land claimant. Moreover, there is another aspect about parcel boundary that affects the value of the land: it is the size of the parcel. Stipulated in *Law No. 28 of 2009* is that the taxation of land and building in rural and urban area is the Selling Value of Taxation Object (SVTO) which comes from the transaction that happened in the market. The value of SVTO is in Rupiah per square meter, consequently the value multiplied by the area will result to the amount of the price of the parcel. Thus, aside from the boundary itself, a generated total area of each parcel will also be evaluated in this study.

– *Boundaries Coordinate*

  Digitized in ArcGIS and then exported into excel data, the coordinates representing the parcel boundaries from UAS based image approach and existing approach were processed in excel to get the difference value between the 2 datasets. Table 17 shows the processing output in excel, X1 and Y1 are coordinates of the dataset acquired using an existing approach, meanwhile X2 and Y2 are coordinates of the dataset acquired using a UAS based image approach. Using these coordinates then, the residuals ΔX (X1-X2) and ΔY (Y1-Y2) were extracted to get the RMSE of the boundaries points.

Table 17: Coordinate and residual of the boundaries points from two different approach

Points ID	X1	Y1	X2	Y2	ΔX (cm)	ΔY (cm)
1.1	523872.924	9008386.161	523872.912	9008386.222	1.224	-6.109
1.2	523880.553	9008428.453	523880.731	9008428.575	-17.824	-12.188
1.3	523919.738	9008415.853	523919.503	9008415.397	23.559	45.634
1.4	523955.633	9008402.377	523955.205	9008402.531	42.779	-15.323

1.5	523941.568	9008361.547	523941.217	9008361.865	35.086	-31.830
1.6	523906.903	9008374.169	523907.464	9008373.857	-56.038	31.120
2.1	523970.782	9008445.067	523970.310	9008445.226	47.193	-15.956
2.2	524006.203	9008433.353	524006.010	9008433.130	19.329	22.337
2.3	523992.722	9008388.284	523992.581	9008387.805	14.144	47.874
2.4	523955.633	9008402.377	523955.205	9008402.531	42.779	-15.323
3.1	523934.352	9008456.567	523934.402	9008456.686	-4.976	-11.926
3.2	523970.782	9008445.067	523970.310	9008445.226	47.193	-15.956
3.3	523955.633	9008402.377	523955.205	9008402.531	42.779	-15.323
3.4	523919.738	9008415.853	523919.503	9008415.397	23.559	45.634
4.1	523773.752	9008398.949	523773.840	9008399.313	-8.723	-36.424
4.2	523758.136	9008401.871	523757.932	9008401.899	20.450	-2.880
4.3	523760.223	9008414.912	523760.036	9008414.873	18.768	3.892
4.4	523776.674	9008411.542	523776.659	9008411.512	1.546	3.033
5.1	523773.752	9008398.949	523773.840	9008399.313	-8.723	-36.424
5.2	523771.368	9008387.817	523771.278	9008387.732	9.057	8.471
5.3	523756.020	9008391.194	523756.039	9008391.230	-1.918	-3.668
5.4	523758.136	9008401.871	523757.932	9008401.899	20.450	-2.880

Generally, the value of the differences between the observed value and predicted value represent the model fitness towards the data. Therefore the smaller the value means the closer it is to the data. Figure 20 shows the residual plot for ΔX and ΔY, where the X axes defines the Point ID meanwhile its Y axes informs the residual value.

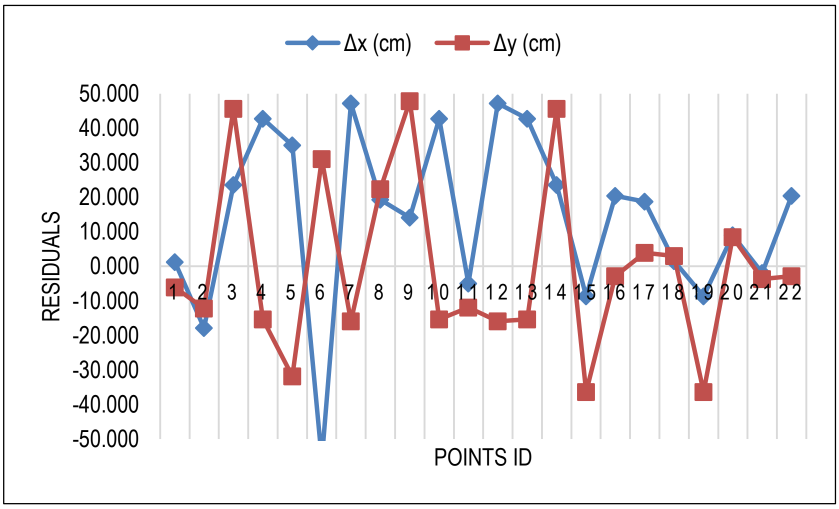

Figure 20: Residual plots of two different approach

– *Parcel Area*

Similar to the parcel coordinates, the digitized parcel area from UAS based image approach and existing approach were generated using ArcGIS. The generated parcel area of 2 datasets was then extracted to get the difference value between the 2 datasets. The Parcel ID in Table 18 was derived from the reference data acquired using the existing approach, and A1 represents the area generated also from the existing approach, meanwhile the A2 column gives the information of area generated from UAS based image approach.

Table 18: Difference area of two datasets

Parcel_ID	A1 (m^2)	A2 (m^2)	A1-A2(m^2)
00245	177.846	180.027	-2.181
00246	213.368	212.040	1.328
00482	1793.956	1773.322	20.634
00483	1725.813	1722.091	3.723
00619	3303.110	3266.925	36.185

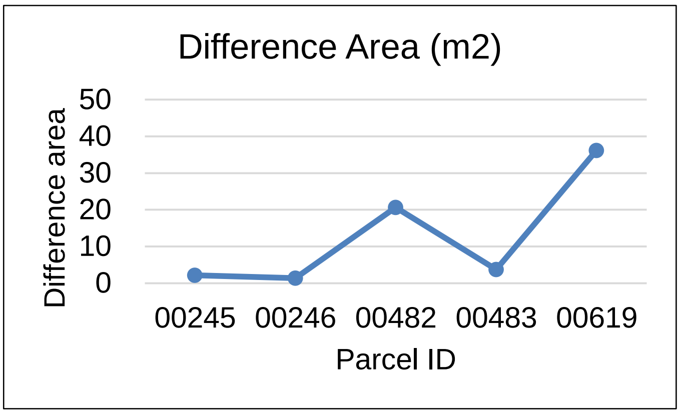

Figure 21: Value of difference area of surveyed parcel

5.2. Concluding Remarks from Evaluation

Participatory

The adherence of the UAS based image approach in terms of its participatory element was seen from the procedure which performed in the field with the participation of the land claimants, neighbours, and village's authorized party. The degree of involvement perceived by the participants during UAS based image approach is considered to be higher than the existing method using terrestrial methods, where 3 participants felt very involved in UAS based image approach and only 1 participant felt very involved in existing method.

From the variety of general opinions given by the participants on UAS based image approach, it is later known that the terms "good" and "sophisticated" appeared more frequent which reflects the opinion on UAS based image approach as a good approach with a sophisticated technology.

Defining something using term "good" can give a vague description. When being asked to elaborate their respond, one of the interviewee said,

"It is a good approach, the boundaries are clearly visible, we can even see our neighbour's boundary also (personal communication, Tendri Ratu, Land Claimant, interview 15-Oct-2015)"

However, it came to the author's attention that the term "vulnerable" was also mentioned by one of the interviewee to describe the new approach.

"The system is vulnerable regarding the boundary issues (personal communication, Hermansyah, Head Village of Lunyuk Ode, interview 15-Oct-2015)."

This point of view is highlighted because it appeared to be the only negative term used by the participant to describe the approach, which is indirectly informing that issues regarding the boundary might appear in the future. Furthermore, the perceived trust towards the accuracy of the generated output from UAS based image approach is 5 out of 6 respondents being very convinced, which is higher than the perceived trust from the existing approach where 2 out of 6 felt very convinced. An interviewee expressed the perceived trust to the accuracy of the output from UAS based image approach is very high because all the boundary are visible.

Duration and Cost

– *Duration*

Results from the evaluation on duration of 2 different approaches also showed improved towards time efficiency with the UAS approach. With the UAS based image approach, it took in total 720 minutes, which is equal to 1 day and 4 hours working time (considering that working hours per day is 7 hours) – to generate 5 parcels. Meanwhile, the existing approach using terrestrial survey took a longer duration of 910 minute (equal to 1 day 7 hour and 10 minute working time) for the measurement of 1 parcel.

It is remarked from the result that the survey duration for the existing approach was allocated longer in the notification stage. In this stage, the land claimant is notified to make an agreement with the neighbours on the parcel boundaries and also prepare the boundary to be marked by monuments/signs to fulfil the delimitation contradictory. Delay caused by the disagreement towards boundaries or the inexistence/uncertain boundary markers will lead to the delay of the whole procedure. This action is taken to avoid any risk on possible legal action happened in the future by surveying the wrong boundaries.

One important thing to be noted also is the fact that the number given for the duration using the UAS based image approach was from the field work which successfully generated 5 parcels as output. Of the duration, the longest duration happened in the stage of image acquisition and processing with 630 minute in total (equal to 1 day 3 hour and 3 minute working time), which successfully managed to capture an area coverage area of 32 Ha with around 240 parcels in it. To be highlighted also, unlike the conventional approach with overall procedure is requesting for user intervention, the UAS based image mostly consists of computational activity which does not require for user interaction i.e. image processing.

– *Cost*

From the cost breakdown for both the UAS based image approach and existing approach, using terrestrial survey, it is revealed that the cost for each parcel boundary survey conducted using UAS based image approaches is IDR 1,054,200. This number is 30% of the cost for boundary survey with the existing approach using terrestrial survey which costs IDR 3,564,000 for each parcel.

The cost is showing a significant difference in some points such as the staff allowances, where the existing approach with terrestrial method required 3 people in the field, therefore the cost is higher. On the other hand, the UAS based image approach gave a high number in terms of purchase/rent of capital equipment due to the high rent of the UAS unit. However, this number is still acceptable since the UAS based image approach successfully generated 5 parcels with a close value of equipment rent used to survey 1 parcel in the existing approach.

Spatial accuracy achieved

The spatial accuracy in this research is categorized into 2: accuracy of the output UAS imagery and digitized parcel boundaries. It should be understood that accuracy gives information on the estimated positional error of the location, which can be derived from the value of RMSE computation.

– *UAS Image Accuracy*

For a comparison, the theoretical accuracy of the imagery was calculated as:

$S_X = m_b \cdot s_x$, where $m_b = \frac{H}{c}$; H is height above ground; sx is pixel size; C is calibrated focal length.

Therefore, the computed theoretical accuracy for X and Y is 3.004 cm. For this research, only the horizontal accuracy will be taken into consideration for its legal implication in cadastral purposes which is still focused on the horizontal scope. As a result, compared to the theoretical accuracy of 3.004 cm for X and Y, the RMSE value of 2.4 cm (X) and 1 cm (Y) are still within range of the expected accuracy which also indicates no systematic error.

This high accuracy fits the expected result from the preparation and flight planning. From the regulation it was known that the largest scale for cadastral purpose in Indonesia is 1:1.000, thus the minimum raster resolution needed to produce this map is 0.5 m. With UAS characteristic which is more flexible to adjust with flying height and flight timing, it gives a possibility to conduct an image acquisition with the requirement mentioned above.

– *Parcel Accuracy*

The residuals between the observed and predicted value from the result represent the model fitness towards the data, the smaller the value means the closer the result is to the data. It is remarked that the result generated from both boundaries and areas of the parcel has shown a significance discrepancy between the parcels.

The smallest residuals for boundary points were from point 1.1 (Figure 23a) and point 4.2 (Figure 23b) with Δx = 1.224 cm and Δy = -2.880 cm, meanwhile the largest residuals were from point 1.6 (Figure 22a) and point 2.3 (Figure 22b) with Δx = -56.034 cm and Δy = 47.874 cm. Similar to the boundary points, the residuals for parcel area also gave a big difference towards the data with smallest residual of -2.181 m2 and largest residual of 36 m2.

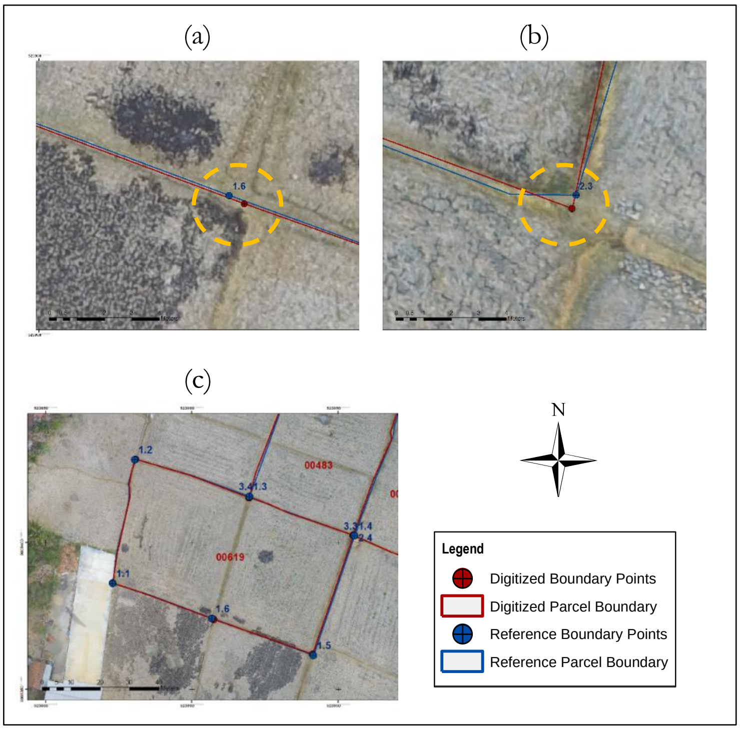

Figure 22: (a) and (b) coordinate boundaries with largest residuals; (c) parcel area with largest residual

The large value of the residuals illustrated the disparities of the boundaries and areas of the parcel which might have caused by the systematic error of the method to delineate the boundaries. From the visual comparison of the digitized output and the referenced parcels observed with the existing method, some of the points were missed to be marked or marked in the different location with the referenced one. Figure 22a and 22b are the examples of the misplaced markings which led to largest residuals. It was seen that in Figure 22a, the boundary which was marked during the participatory mapping is located in a different place with the one observed with existing terrestrial approach (referenced boundary). Figure 22b also illustrated the discrepancies that there is a detail of one boundary marking existed in the referenced boundary (blue line) and not in the digitized boundary from the UAS based image (red line).

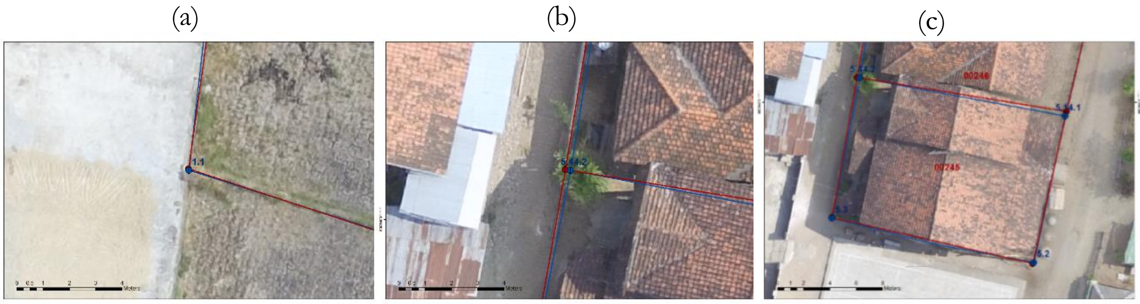

Figure 23: (a) and (b) coordinate boundaries with smallest residuals; (c) parcel area with smallest residual

As a result of the discrepancies in boundary coordinates, the parcel area generated also gave the large residuals. Visualized in Figure 22c, parcel 00619 is located in the field with a visible line of natural boundary. To recall on what happen in the field during data collection, the land claimants were asked to show their boundaries directly on the image map, then by the agreement with the adjacent neighbours and known by the authorized party of the village, the boundaries were marked and then signed with the land claimant's name on it. During this method, the possibility of misplacing or deficient details on marking the boundaries might lead to errors in the parcel area generated from the boundaries coordinates. Therefore it is very important to deliver the message on how the method actually works to all the parties involved in the method, and what information should be given by all the respondents – so the output resulted will be the representation on the actual boundaries.

Furthermore, the analysis towards the smallest residuals showed that the coordinate which are located in a man-made or built-up boundaries gave a better result than the natural boundaries. The coordinate residuals of 1.224 cm in point 1.1 (figure 23a) and -2.880 cm in point 4.2 (figure 23b) are still within the expected accuracy. The parcel area located in the residential area, where the boundaries are indicated with a built-up fence, also gave the smallest residual. With the residual of -2.181 m2 which is still high for the cadastral purpose, the parcel area with more visible and clear boundaries line are proven to be able provide the better result than the natural features.

One of the incidental findings from the field data collection was a parcel showing in the image map was unclear due to the coverage by vegetation. Therefore, a field check was held before marking the boundaries. Figure 24 visualizes the result of the digitized parcel from the UAS based image and the referenced boundary from the existing approach. It was also found from the residual result that the boundary is giving an acceptable coordinate boundary with residual of 18,768 cm (Δx) and 3.892 cm (Δy).

Figure 24: Point 4.3 with blocked coverage of vegetation

Another possibility of error might be in the referenced data itself. Although it is assumed that the referenced boundaries measured with the existing terrestrial approach is already correct and update, the possibility of inaccuracy might still exist, given that the current method was acquired using combination of measuring tape, TS, and GNSS RTK – with variety of accuracies within mm to cm.

5.3. Summary of Chapter 5 – Evaluation

The new designed approach is assessed in this chapter. The assessment is conducted using 4 elements of fit-for-purpose criteria: participatory, attainable, affordable and reliable. Throughout the comparison with the existing terrestrial method, the UAS based image approach showed a high perceived involvement – three out of 6 respondents felt very involved. The duration and cost evaluation of UAS based image approach also indicates an efficiency improvement. In 720 minutes, the new designed approach is able to capture images of 32 Ha and generate 5 parcels. It is also revealed that the cost per parcel for the new approach is IDR 1,078,200 ≈ USD 80. In addition, the UAS image has a horizontal accuracy of 2.8 cm, thus it enables to produce the output with the similar high accuracy. However, the evaluation towards the parcel generated from the UAS imagery shows a significance discrepancies between the parcels. The source of errors might have come from the systematic error of the method to delineate the boundaries – which was obtained with participatory boundary mapping, or the referenced data itself – which was surveyed with combination of measuring tools.

6. DISCUSSION AND RECOMMENDATIONS

The last chapter delivered the assessment of the specific results and this chapter discusses the overall result and the compromises and decisions that had to be taken during the research – and should be taken into account when reading. An assessment of the UAS based image approach in general will also be discussed: the SWOT (Strengths, Weakness, Opportunities, and Threats) tool will be used to provide a comprehensive summary of major constraints and opportunities to improve the approach.

6.1. Discussion

The regulated procedure of cadastral boundary data acquisition in Indonesia already enables the implementation of photogrammetric methods in cadastral boundary survey and mapping. However, it is not practical to implement the procedure: photo maps, if they exist are only used for sketch maps and support. Indeed, the terrestrial method reigns supreme. At any rate, this provision for allowing photogrammetric methods indicates that a revision towards the regulation is needed given the availability of improved imagery based techniques and technologies in the contemporary era. Another issues on implementing the image/photo map approach for boundary delimitation in Indonesia is the unavailability of high resolution image that fulfil the requirement of cadastral purpose (Feryandi et al., 2014; Sadikin et al., 2014).

The review on UAS implementation showed that it is possible to conduct survey and mapping using UAS for cadastral purposes. The regulation issued regarding the UAS operation also allows the application of UAS for any purpose with flying height below 150 m. Based on the regulation compliance towards the use of UAS for cadastral purpose, a designed flowchart to conduct the boundary survey using UAS based image approach can then be executed.

The approach developed utilized the UAS image map and participation of the community to delineate the parcel boundaries. It is proven to be able practically produce high resolution imagery in a shorter period and lower cost than the conventional aerial photogrammetry or satellite based methods – over a small area. Based on the author's experience, the procurement system to get the product of aerial photogrammetry and satellite imageries was a long process, let alone using it to generate parcel boundaries. The fact that Indonesia also has a challenging topography with often hilly and dense vegetation also creates problems when a terrestrial survey should be conducted to record the parcel in that kind of area. The issues of the unavailability of a base map for cadastral purpose, due to improper resolution of current infrastructure and everlasting cloud cover in some regions, should also not be forgotten. Throughout this approach, tackling all the matters and carrying out the survey to produce an update high resolution imageries appears a pragmatic option, and achievable.

Generating boundaries from UAS images with participatory mapping is not a new thing. It is noticed that the use of UAS in Indonesia has been well developed since its first application, including for boundary delimitation in counter-mapping land grabs (Radjawali & Pye, 2015), which demonstrated how drone technology becomes more accessible than former counter-mapping technologies with actively involved community members. Throughout the involvement of the community in mapping for cadastral purpose, it is not only the essential information of the boundaries itself that could be derived, but also the acknowledgement of all the parties involved through the agreement is enable to be gained.

On the other side, the implementation of UAS as a new technology will spur the need for development of the equipment, regulations and capacity building in the future. With the high accuracy of UAS imagery (able to produce of 2.8 cm), although the residual of the parcel generated from UAS based image approach and the existing approach using terrestrial resulted in being too high and not acceptable for cadastral purpose, it is still highly possible to generate parcels with a similar spatial accuracy achieved by the UAS image. Furthermore, the method applied for participatory boundary mapping is proven to have a great influence on the parcel boundaries as the output. Therefore, all parties involved should understand the approach at the start by recognizing their role and giving the detailed information towards the parcel boundaries. It also needs to be understood, with the fact that the number of participants involved in the participatory boundary mapping to test the procedure was low, an indication of possibility bias for the evaluation of response and level of participatory involvement might also have happened.

Throughout an evaluation with fit-for-purpose elements, the compliance towards the result is given in Table 19.

Table 19: UAS based image approach compliance towards fit-for-purpose elements

Elements	Result Compliance
Participatory	Yes – Participation of all the parties involved (land claimants, neighbours, and authorized party from the village) is the requirement to conduct the approach.
Attainable (Duration)	Yes – In 630 minutes it is possible to capture an area with around 240 parcels in it. It took 720 minutes to generate 5 parcels, meanwhile the existing procedure required 910 minutes to get the output of 1 parcel.
Affordable (Cost)	Yes – Cost per parcel is 70% lower than the existing approach with terrestrial survey.
Reliable (Accuracy)	Yes – Accuracy of the coordinate boundaries digitized from the participatory boundary mapping are varies from 1.224 cm to 56.034 cm, it is promising to improve the accuracy given that the image map is very high (3.004 cm).

6.2. Recommendations

6.2.1. SWOT Analysis

It is reasonable to have an approach with advantages and limitations on its implementation. Through investigation towards the benefits and drawbacks of the UAS based image approach, recommendation for further research will be delivered from the situational analysis given in the *Strengths Weaknesses Opportunities and Threats (SWOT)* analysis of the approach.

Table 20: SWOT matrix for UAS based image approach

Strengths	Weaknesses
– Approach was developed and adjusted based on the compliance on the regulation and requirement of cadastral purpose, where all stages development were approved by the authorized field executors; – Approach is proven to be more efficient in generating more parcels in an adjacent area; – Approach promotes high involvement of the surrounding community; – Approach can produce highly spatially accurate output;	– Approach has a high dependency on the participation of the community; – Residuals for parcel area achieved still does not fit the existing cadastral requirements; – Invisible boundary (e.g. vegetation) on the screen requires for ground investigation; – Approach involves a new technology and requires high specification on Geo-ICT support; – Approach has a high dependency to electricity power;

– Approach can be used in location without base map and can produce an updated base map for cadastral purpose in a shorter period and lower cost – over a small area; – Approach can be used to survey an area with challenging topography (hilly and dense vegetation); – Approach was applied using resources of the actual cadastral executors (BPN).	– Approach is not efficient if implemented for only one parcel.
Opportunities	Threats
– Existence of regulation on the use of photogrammetry for boundary survey; – Law compliance with the use of UAS for cadastral purposes in Indonesia; – Availability of infrastructures and human resources with adequate background for cadastral surveying and mapping; – High interest and motivation towards the UAS based image approach; – Open-source software for (UAS) image processing are available; – New application, tools and technology to utilize digital image and cadastral data are available; – There are still high number of parcels to be certified in Indonesia. – Indonesian policy to increase registered parcel numbers.	– Executor institution (BPN) is still lacking of cadastral survey and mapping facilities and infrastructure - establishing a new system might add another load for the institution; – BPN is still lacking of human resources with adequate skill to run the approach; – There is a frequent power cut problems; – Not everyone can read maps – or imagery.

6.2.2. Recommendations for Approach Improvements

Through an analysis of the approach benefits and drawbacks elaborated using the SWOT analysis tool, a list of recommendations are proposed for further improvements in both internal and external elements of the approach. They are:

- *Approach enhancement:* Develop comprehensive guidelines and quality control of the whole procedure (including the involvement of the community); modify the system to enable it to be combined with other available infrastructures and latest tools and technologies; include the characteristic of the community to develop a more friendly, applicable, reliable and inclusive approach.
- *Approach utilization:* Increase the efficiency of cost, time and labour by using UAS based image approach in areas with no base map or challenging topography; deliver an updated output (UAS image map) in the approach to avoid misinterpretation; use the approach for mass-registration parcel instead of single-registration parcel (in viable areas); maintain good trust towards the parties involved by implementing the ethical guide of good practices for participatory mapping.
- *Institution capacity and facility improvement:* Improve the existing regulation on cadastral boundary survey to be adaptive with the needs of society and also development of tools and technologies available; build and maintain the available human resources capacity and infrastructures to increase the institution capacity in supporting their cadastral boundary survey and mapping infrastructure development through the utilization of UAS; improve the institution facility by providing adequate infrastructure, equipment and emergency power supplies.

7. CONCLUSSION

The main objective of the thesis is to ascertain whether UAS technology enables acquisition of cadastral boundary data in a fit-for-purpose manner in Indonesia. Among the variety of available approaches for cadastral data acquisition worldwide nowadays, the use of imagery to generate a general boundary has been emerging as one of the tools for the projected new era in land administration. Recent experiences from Rwanda, Ethiopia and Lesotho, along with older ones from Thailand, already demonstrate the potential. UAS with their capacity to operate in a more flexible way was investigated through a sequence of procedures, starting from reviewing the current status and requirements, developing and applying the methods, and finally evaluating the new approach.

The first sub-objective is to review the requirement of Indonesian cadastral boundary needs and current status of UAS in Indonesia. Responded the research question 1.1. and 1.2., the review reveals that the use of photo map in cadastral data acquisition and UAS operation has been regulated explicitly by the Government of Indonesia. Run by National land Agency (BPN), the cadastral data acquisition is still undertaken with terrestrial method using measuring tape, ETS, and GNSS. It also affirms that operating UAS for cadastral purposes complies with the regulation that was issued in mid of 2015 as the research was about to commence. On the other hand, the policy that regulates the cadastral boundary data acquisition is considered to be outdated. Specifically in the section of boundary mapping using a photo map, it is still inefficiently including the terrestrial survey – whilst the photo map is just used for sketch map.

The second sub-objective is to develop a UAS based image approach for cadastral boundary data acquisition in Indonesia. Taking the result from the review/requirements stage, a flowchart for a UAS based cadastral data collection approach, with an adaptive procedure of ortho-photo generation, and participatory mapping, was then developed and tested to respond research question 2.1. and 2.2. The test result delivered output of imagery with 2.8 cm horizontal accuracy, conducted within 720 minutes for 5 parcels, and costs IDR 1,078,200 ≈ USD 80 for each parcel. Including participatory mapping to generate the cadastral boundary set a high dependency to the community. How the map is made for the community and by the community enables the delivery of acknowledgement of all parties involved through the boundary agreements made. Given the fact that there is no global official standard guidance and quality control in conducting delimitation boundary survey using photo map with the community involvement, further studies regarding this issue is suggested. An assessment of the model to control or evaluate the approach is needed to give assurance on boundary certainty as what the monumented boundary is able to deliver.

The third sub-objective is to evaluate the UAS based image approach for cadastral boundary data acquisition in Indonesia in terms of the elements of fit-for-purpose. Overall, the developed approach, when tested, showed adherence to the elements of fit-for-purpose used for evaluation (participatory, attainable, reliable, and affordable). Throughout the development and testing of the UAS based approach, it was revealed that the approach, which includes the high involvement of the community, is proven to be more efficient in generating more parcels in an adjacent area. It is also promising to produce high accuracy output using the ortho-photo with 2.8 cm horizontal accuracy. The results also indicate that the other elements which were not included for the evaluation - such as flexible, inclusive and upgradeable – are also potentially supported by the approach. The approach is flexible with its ability to adjust on a range of requirements such as spatial accuracy, purposes, temporal needs and geographical characteristics. The information delivered by the output imagery from the approach is also embracing all area coverage captured inclusively – thus it is popular in participatory mapping involving the indigenous/community needs. Given that the approach was triggered by substantial benefits offered by UAS, deeming it as a revolutionizing tool in land administration, enhancing it by integration of latest technologies in data collection and information systems opens up the possibilities towards an improved land administration systems.

With regards to the future outlook, when considering Indonesia's national cadastre challenge, the approach is likely to support resolving the issue of the low numbers of certified land and low assurance of boundary certainty towards forestry and non-forestry specified in *Medium Term National Development Plan of Indonesia (2015-2019)*. Meanwhile, in relation to the result of this study which only took the 2D plane into consideration, another further investigation is also promising to be done regarding the potential characteristics of future cadastres which include the 3D representation of properties.

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APPENDIX 1

List of Legislation Document Related to the Procedure of Cadastral Boundary data Acquisition in Indonesia

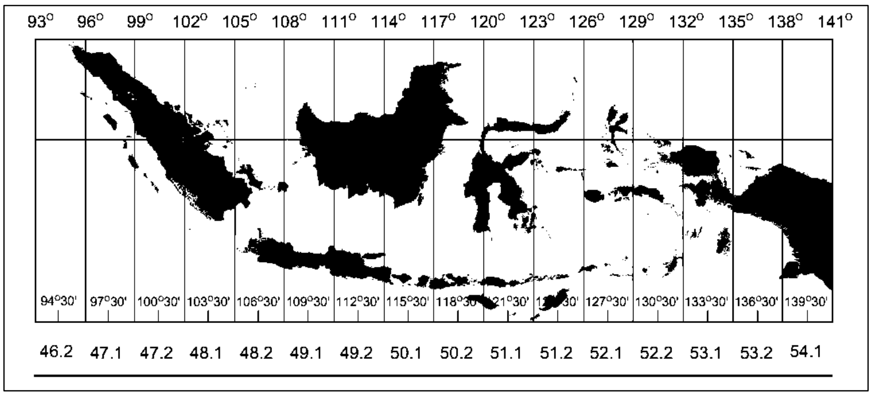
No	Document	Article/Section	Subject	Relevance
1	*The Constitution of the Republic Indonesia 1945*	Article 33 Clause 3	The authorization of land, water, and natural resource of Indonesia.	Basic regulation for Indonesian cadastral system.
2	*Basic Agrarian Law Number 5 of 1960*	Chapter II, Section II, Article 19, Clause 2.a.	Land Registration	Activities of surveying, mapping, and recording land are included in the activity of land registration.
3	*People's Consultative Assembly Decree IX of 2001*	Article 5, Clause 1.c.	Agrarian Reform Policy	Implementation of land arrangement through the inventory and registration of control, ownership, use and cultivation of land comprehensively and systematically in order to implement land reform.
4	*Geospatial Information Law Number 4 of 2011*	Chapter 3, section 3; Chapter 14; Chapter V; Chapter VI	Geospatial Information	Description of the rules about thematic geospatial Information establishment. Considered as thematic geospatial information, the establishment of cadastral boundary should follow the rules of geospatial data elaborated in this law.
5	*Government Ordinance Number 24 of 1997*	Article 14	Land Registration	Cadastral surveying and mapping to collect and process the physical data include 5 activities: registration base mapping; delineation cadastral boundary; cadastral survey and mapping and registration mapping; creating list of land; and survey letter issuance.
6	*Government Ordinance Number 13 of 2010*	Article 1 to 4	Non-Tax Revenue of Surveying	Formulation of the fees for the non-tax revenue service in cadastral survey and mapping.
7	*Presidential Decree Number 34 of 2003*	Article 1	National policy of land	Cadastral mapping using satellite image and information technology.

No	Document	Article/Section	Subject	Relevance
8	*Presidential Decree Number 85 of 2007*	Article 5 to 7	National Spatial Data Network	Department/Ministry which included in network node of National Spatial Data Network has responsibility to build, coordinate, and develop their own spatial data. In this case, BPN has the responsibility to maintain the cadastral framework and parcels in such a format that it can be exchanged and disseminated publicly.
9	*Presidential Decree Number 17 of 2015*	All	Ministry of Agrarian and Spatial Planning	Ministry of ATR/BPN as policy maker and implementer regarding cadastral surveying, measurement and mapping.
10	*Presidential Decree Number 20 of 2015*	All	National Land Agency	BPN as policy maker and implementer regarding cadastral surveying, measurement and mapping, coordinated with Ministry of Agrarian and Spatial Planning.
11	*Regulation of the State Minister of Agrarian Affairs/Head of National Land Agency Number 3 of 1997*	All	Provision of Government Regulation Implementation	Explanation of cadastral survey and mapping procedure in Indonesia.
12	*Regulation of the State Minister of Agrarian Affairs/Head of National Land Agency Number 1 of 2010*	Appendix II Part IV	Standard for Land Service and Arrangement	Procedure and duration on cadastral surveying.
13	*Regulation of the State Minister of Finance Number 51 of 2012*	Article 1	Index Rate Calculation of Non-Tax Revenue	List of unit price for special fee in surveying to calculate the surveying service fee in Ministry of ATR/BPN.
14	*Regulation of the State Minister of Agrarian Affairs/Head of National Land Agency Number 2 of 2013*	Chapter IV, Section 1	Delegation of authority regarding land titling and land registration	Authorities and mechanism of survey letter and plot map signing.

No	Document	Article/Section	Subject	Relevance
15	*National Land Agency Technical Instructions and Guidelines for Survey and Mapping Procedure*	Chapter V	Survey, measurement and mapping procedures in National Land Agency	Detail explanation of activities included in cadastral survey and mapping procedure in Indonesia.

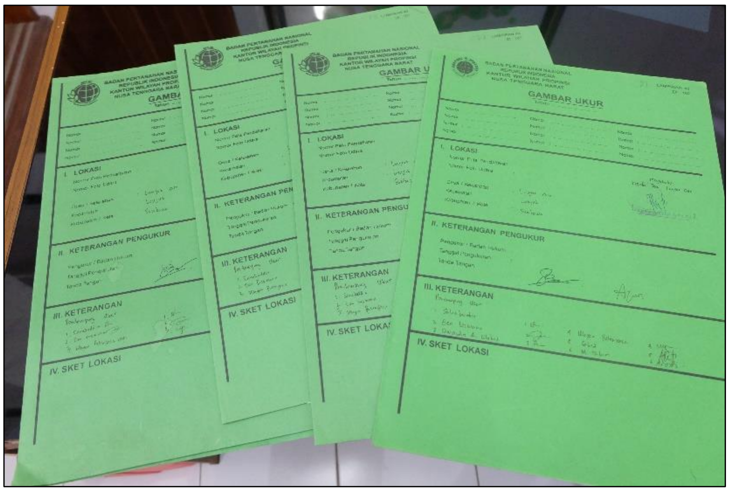
APPENDIX 2

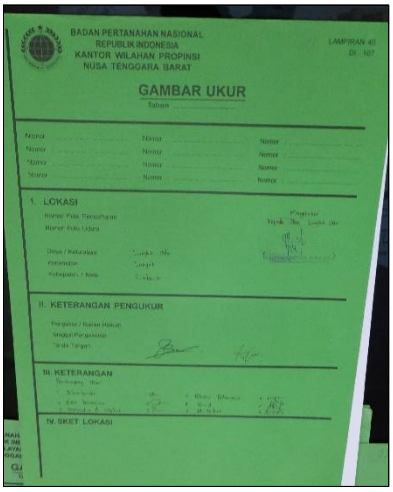
TM-3°

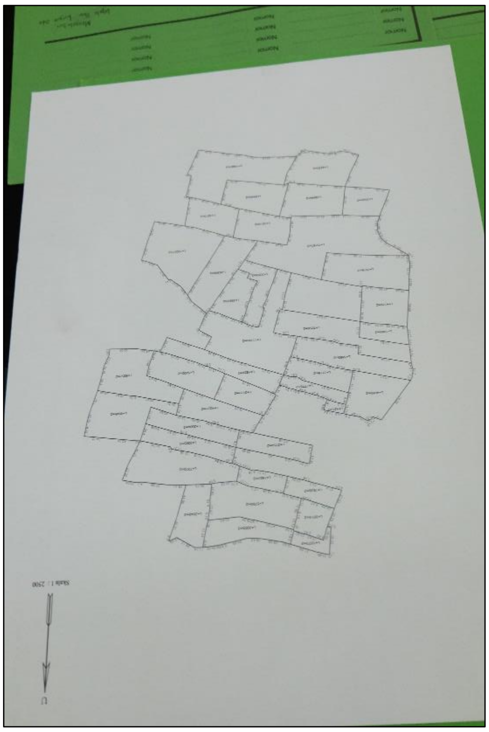
Description	:	Coordinate reference system used for cadastral purposes in Indonesia. It has a wide zone of 3 degrees, meanwhile Universal Transverse Mercator (UTM) zone has a width of 6 degrees. It divides the UTM zone into 2 parts, for example UTM zone 50 is divided as TM-3 zone 50.1 and TM-3 zone 50.2.
Datum	:	DGN 95 / WGS 1984, a= 6387137 and $f=\frac{1}{298.25722357}$
Projection	:	Transverse Mercator
Parameter	:	False Easting = 200000; False Northing= 1500000; Scale Factor = 0.9999; Latitude of Origin = 0o; Linear unit = Meter
Linear Unit	:	Meter
Zoning	:	

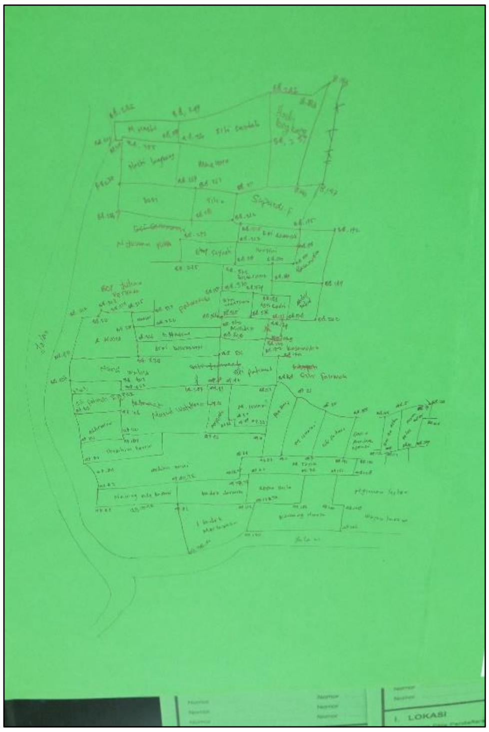
APPENDIX 3

Survey Drawing









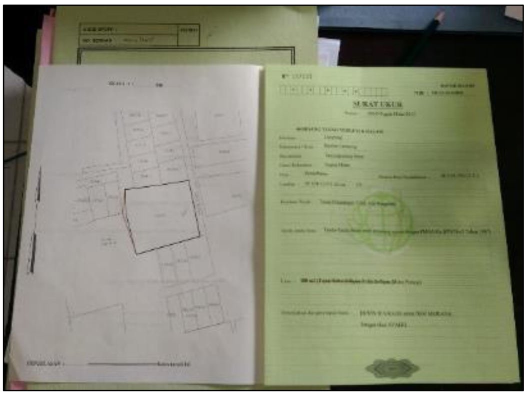
APPENDIX 4

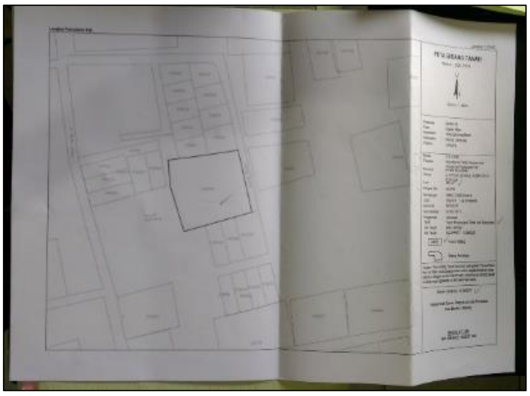
Registered Land Listing

NIB	NO BERKAS	LUAS	LEMBAR	KOTAK	NAMA FIX	LOKASI	PENGGUNAAN	PEMANFAATAN
00711	6119	770	05.038-10-9	E2	Yudiansyah	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00712	6120	2510	05.038-11-7	B1	Dalima	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00482	6121	1795	05.038-11-4	A4	Endang Srianti	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00378	6122	1789	05.038-11-7	C3	Ilham Handika	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00568	6123	2000	05.038-15-1	D1	Mastari	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00621	6124	3436	05.038-11-7	A1	A. Wahab	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00734	6125	1150	05.038-11-7	B2	Aditya Wirawan	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00480	6126	724	05.038-10-6	E5	Darlina	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00479	6127	1639	05.038-11-4	A5	Gita Pranata	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00376	6128	4635	05.038-11-7	B3	Napis Majid	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00487	6129	1503	05.038-11-7	B2	Zaifah	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00485	6130	4553	05.038-11-4	B5	Nurwana	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00713	6131	2058	05.038-11-7	B1	Tawalani	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00486	6132	2937	05.038-11-7	B1	Supiatun	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00379	6133	779	05.038-10-9	E2	Ardiansyah	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00883	6134	1802	05.038-11-4	A1	Maemuna	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00562	6135	9456	05.038-11-7	C5	Amri Rahman	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00660	6136	1332	05.038-11-7	C3	Hamidah	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00682	6137	1991	05.038-15-1	E1	A. Rauf	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00620	6138	808	05.038-10-6	E4	Satria Ardiyansyah	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah
00494	6139	1316	05.038-11-7	D4	Husain	Desa Lunyuk Ode Kecamatan Lunyuk	Tanah Tidak Ada Bangunan	Pertanian Tanah Basah

APPENDIX 5

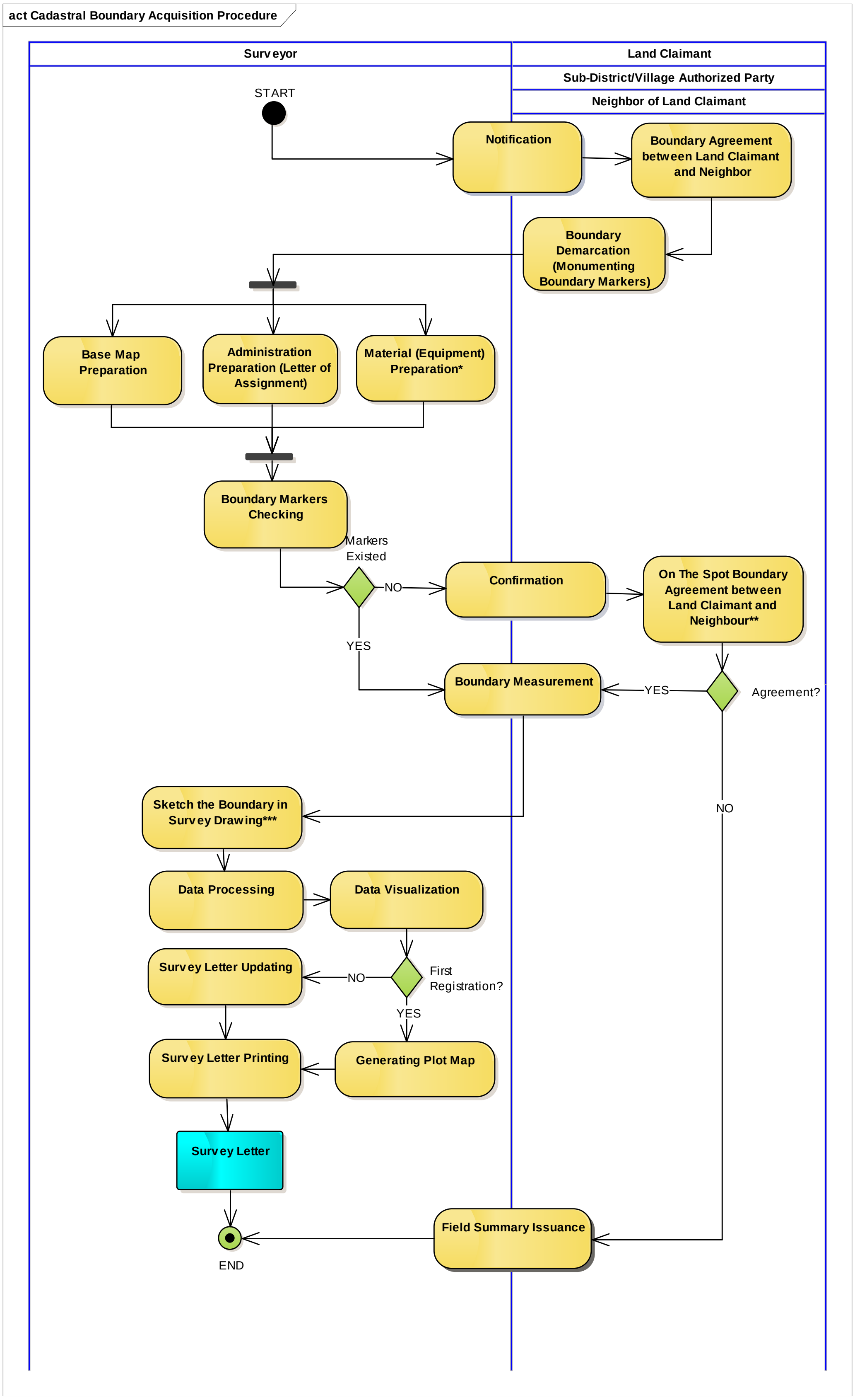
Survey Letter and Plot Map





APPENDIX 6

Flow Chart of Existing Cadastral Boundary Data Acquisition in Indonesia



Note:
*) Instrument of measurement depends on the field condition and situation: 3 are > 300 m2 use non-measuring tape e.g. ETS, GNSS RTK.
**) Measurement is not possible to be conducted due to the existence of dispute or disagreement on the boundary. A field summary will be issued and signed by the land claimant and neighbours, acknowledged by sub-district/village authorized party;
***) Regarding to uncertainty during the boundary measurement, the measurement can be conducted but the boundary will be sketched with dotted line in measurement drawing.

APPENDIX 7

The Unit Price for Special Fee (HSBKu) in Surveying in Indonesia (IDR)

No	Provinsi	HSBKu Agriculture	HSBKu Non Agriculture
1	Aceh	50,000	100,000
2	Sumatera Utara	50,000	100,000
3	Bengkulu	30,000	60,000
4	Jambi	50,000	100,000
5	Riau	60,000	120,000
6	Sumatera Barat	50,000	100,000
7	Sumatera Selatan	50,000	100,000
8	Lampung	40,000	80,000
9	Kepulauan Bangka Belitung	50,000	100,000
10	Kepulauan Riau	50,000	100,000
11	Banten	50,000	100,000
12	Jawa Barat	50,000	100,000
13	DKI Jakarta	60,000	120,000
14	Jawa Tengah	40,000	80,000
15	Jawa Timur	50,000	100,000
16	DI Yogyakarta	40,000	80,000
17	Bali	50,000	100,000
18	Nusa Tenggara Barat	30,000	60,000
19	Nusa Tenggara Timur	20,000	40,000
20	Kalimantan Barat	40,000	80,000
21	Kalimantan Selatan	50,000	100,000
22	Kalimantan Tengah	50,000	100,000
23	Kalimantan Timur	60,000	120,000
24	Gorontalo	30,000	60,000
25	Sulawesi Selatan	40,000	80,000
26	Sulawesi Tenggara	40,000	80,000
27	Sulawesi Tengah	40,000	80,000
28	Sulawesi Utara	50,000	100,000
29	Sulawesi Barat	30,000	60,000
30	Maluku	20,000	40,000
31	Maluku Utara	20,000	40,000
32	Papua Barat	50,000	100,000
33	Papua	50,000	100,000

APPENDIX 8

Ortho-photo – Output Imagery Processed in the Field using *Agisoft Photoscan*

APPENDIX 9

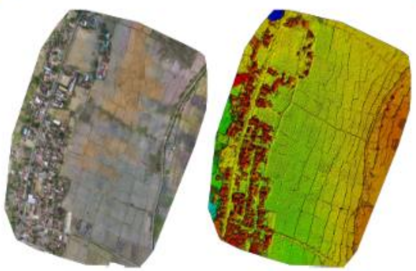
Scanned Manually Mosaicked and Digitized Ortho-photo

APPENDIX 10

Ortho-photo – Output Imagery Re-processed using *Pix4D Mapper*

APPENDIX 11

Quality Report Ortho-photo from *Pix4D Mapper* (Page 1-6 out of 20)



Quality Report

Generated with Pix4Dmapper Pro - TRIAL version 2.0.89

Important: Click on the different icons for:

Help to analyze the results in the Quality Report

Additional information about the sections

Click here for additional tips to analyze the Quality Report

Summary

Project	lunyuk_ode
Processed	2015-12-08 11:13:49
Average Ground Sampling Distance (GSD)	2.99 cm / 1.17 in
Area Covered	0.3281 km² / 32.8132 ha / 0.1268 sq. mi. / 81.1252 acres

Quality Check

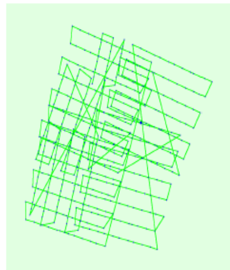
Images	median of 48035 keypoints per image
Dataset	532 out of 532 images calibrated (100%), 3 images disabled
Camera Optimization	0.32% relative difference between initial and optimized internal camera parameters
Matching	median of 7817.39 matches per calibrated image
Georeferencing	yes, 18 GCPs (18 3D), mean RMS error = 0.018 m

Preview

Figure 1: Orthomosaic and the corresponding sparse Digital Surface Model (DSM) before densification.

Calibration Details

Number of Calibrated Images	532 out of 535
Number of Geolocated Images	535 out of 535



Initial Image Positions

Figure 2: Top view of the initial image position. The green line follows the position of the images in time starting from the large blue dot.

Computed Image/GCPs/Manual Tie Points Positions

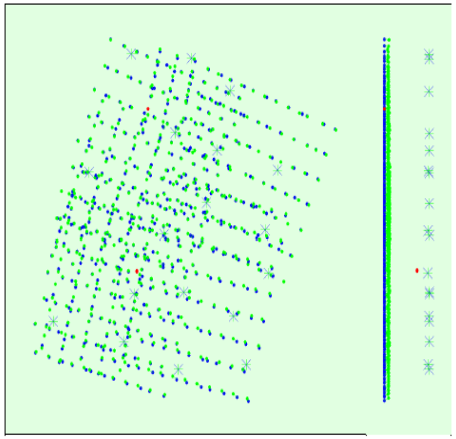


Figure 3: Offset between initial (blue dots) and computed (green dots) image positions as well as the offset between the GCPs initial positions (blue crosses) and their computed positions (green crosses) in the top-view (XY plane), front-view (XZ plane), and side-view (YZ plane). Red dots indicate disabled or uncalibrated images.

Overlap

Number of overlapping images: 1 2 3 4 5+

Figure 4: Number of overlapping images computed for each pixel of the orthomosaic.
Red and yellow areas indicate low overlap for which poor results may be generated. Green areas indicate an overlap of over 5 images for every pixel. Good quality results will be generated as long as the number of keypoint matches is also sufficient for these areas (see Figure 5 for keypoint matches).

Bundle Block Adjustment Details

Number of 2D Keypoint Observations for Bundle Block Adjustment	4428159
Number of 3D Points for Bundle Block Adjustment	1737286
Mean Reprojection Error [pixels]	inf

Internal Camera Parameters

New_FC300S_3.6_4000x3000 (RGB). Sensor Dimensions: 6.317 [mm] x 4.738 [mm]

EXIF ID: FC300S_3.6_4000x3000

	Focal Length	Principal Point x	Principal Point y	R1	R2	R3	T1	T2
Initial Values	2701.820 [pixel] 4.267 [mm]	2001.650 [pixel] 3.161 [mm]	1484.210 [pixel] 2.344 [mm]	-0.009	-0.008	0.037	0.000	-0.001
Optimized Values	2710.680 [pixel] 4.281 [mm]	2001.825 [pixel] 3.162 [mm]	1483.500 [pixel] 2.343 [mm]	-0.009	-0.008	0.038	0.000	-0.001

The number of Automatic Tie Points (ATPs) per pixel averaged over all images of the camera model is color coded between black and white. White indicates that, in average, more than 16 ATPs are extracted at this pixel location. Black indicates that, in average, 0 ATP has been extracted at this pixel location. Click on the image to the see the average direction and magnitude of the reprojection error for each pixel. Note that the vectors are scaled for better visualization.

2D Keypoints Table

	Number of 2D Keypoints per Image	Number of Matched 2D Keypoints per Image
Median	48035	7817
Min	20407	1193
Max	75568	21674
Mean	48380	8324

3D Points from 2D Keypoint Matches

	Number of 3D Points Observed
In 0 Images	9531
In 2 Images	1239278
In 3 Images	277560
In 4 Images	100362
In 5 Images	45863
In 6 Images	27218
In 7 Images	15389
In 8 Images	8976
In 9 Images	4967
In 10 Images	2875
In 11 Images	1735
In 12 Images	1070
In 13 Images	680
In 14 Images	527
In 15 Images	352
In 16 Images	265
In 17 Images	204
In 18 Images	144
In 19 Images	96
In 20 Images	63
In 21 Images	39
In 22 Images	18
In 23 Images	20
In 24 Images	23
In 25 Images	9
In 26 Images	7
In 27 Images	5
In 28 Images	4
In 29 Images	1
In 30 Images	4
In 31 Images	1

2D Keypoint Matches

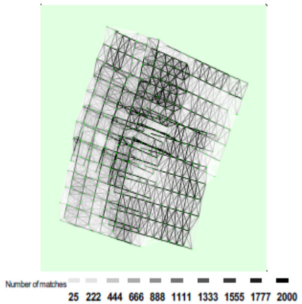


Figure 5: Top view of the image computed positions with a link between matching images. The darkness of the links indicates the number of matched 2D keypoints between the images. Bright links indicate weak links and require manual tie points or more images.

Geolocation Details

Ground Control Points

GCP Name	Accuracy XY/Z [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]	Verified/Marked
1.2 (3D)	0.020/ 0.020	0.015	0.024	-0.000	0.812	8 / 8
1.3 (3D)	0.020/ 0.020	0.031	0.010	-0.005	1.000	25 / 25
1.6 (3D)	0.020/ 0.020	-0.003	-0.012	0.003	0.892	14 / 14
1.7 (3D)	0.020/ 0.020	0.020	0.001	-0.006	0.929	25 / 25
1.8 (3D)	0.020/ 0.020	-0.003	-0.002	0.015	0.666	8 / 8
1.9 (3D)	0.020/ 0.020	-0.022	0.040	-0.020	0.649	16 / 16
1.11 (3D)	0.020/ 0.020	-0.028	0.025	-0.003	0.504	6 / 6
1.12 (3D)	0.020/ 0.020	0.011	-0.000	-0.003	0.885	17 / 17
1.15 (3D)	0.020/ 0.020	-0.005	0.015	0.031	0.626	25 / 25
1.16 (3D)	0.020/ 0.020	-0.028	-0.008	-0.002	0.542	15 / 15
1.17 (3D)	0.020/ 0.020	-0.039	0.002	-0.008	0.483	11 / 11
1.18 (3D)	0.020/ 0.020	-0.026	-0.003	0.010	0.899	10 / 10
1.19 (3D)	0.020/ 0.020	-0.016	-0.026	0.010	0.681	7 / 7
1.20 (3D)	0.020/ 0.020	0.019	-0.029	-0.011	0.588	11 / 11
1.21 (3D)	0.020/ 0.020	0.027	0.007	0.007	0.761	24 / 24
1.22 (3D)	0.020/ 0.020	0.019	0.009	-0.002	0.940	26 / 26
1.23 (3D)	0.020/ 0.020	-0.020	-0.033	-0.025	0.861	21 / 21
1.25 (3D)	0.020/ 0.020	0.041	-0.022	0.005	0.790	34 / 34
Mean [m]		-0.000530	-0.000060	-0.000255		
Sigma [m]		0.023360	0.019158	0.012502		
RMS Error [m]		0.023366	0.019158	0.012504		

0 out of 3 check points have been labeled as inaccurate.

Check Point Name	Accuracy XY/Z [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]	Verified/Marked
1.1	0.0200/0.0200	0.0033	0.0100	0.0577	0.8132	17 / 17
1.5	0.0200/0.0200	0.0401	0.0363	-0.0514	1.0753	19 / 19
1.24	0.0200/0.0200	0.0336	0.0008	-0.0011	0.8310	25 / 25
Mean [m]		0.025651	0.015719	0.001744		
Sigma [m]		0.016049	0.015058	0.044591		
RMS Error [m]		0.030258	0.021768	0.044625		

Localisation accuracy per GCP and mean errors in the three coordinate directions. The last column counts the number of calibrated images where the GCP has been automatically verified vs. manually marked.

Absolute Geolocation Variance

0 out of 532 geolocated and calibrated images have been labeled as inaccurate.

Min Error [m]	Max Error [m]	Geolocation Error X [%]	Geolocation Error Y [%]	Geolocation Error Z [%]
-	-15.00	0.00	0.00	0.00
-15.00	-12.00	0.00	0.00	0.00
-12.00	-9.00	0.00	0.00	0.00
-9.00	-6.00	5.26	2.07	0.00
-6.00	-3.00	9.59	11.28	0.00
-3.00	0.00	37.22	36.47	53.01
0.00	3.00	31.95	38.16	46.80
3.00	6.00	11.65	10.90	0.19
6.00	9.00	4.14	1.13	0.00
9.00	12.00	0.19	0.00	0.00
12.00	15.00	0.00	0.00	0.00
15.00	-	0.00	0.00	0.00
Mean [m]		0.016926	-0.962479	8.390971
Sigma [m]		3.288869	2.633757	0.974993
RMS Error [m]		3.288912	2.804112	8.447426

Min Error and Max Error represent geolocation error intervals between -1.5 and 1.5 times the maximum accuracy of all the images. Columns X, Y, Z show the percentage of images with geolocation errors within the predefined error intervals. The geolocation error is the difference between the intial and computed image positions. Note that the image geolocation errors do not correspond to the accuracy of the observed 3D points.

Geolocation Bias	X	Y	Z
Translation [m]	0.016926	-0.962479	8.390971

Bias between image initial and computed geolocation given in output coordinate system.

Relative Geolocation Variance

Relative Geolocation Error	Images X [%]	Images Y [%]	Images Z [%]
[-1.00, 1.00]	82.89	94.92	100.00
[-2.00, 2.00]	100.00	100.00	100.00
[-3.00, 3.00]	100.00	100.00	100.00
Mean of Geolocation Accuracy [m]	5.000000	5.000000	10.000000
Sigma of Geolocation Accuracy [m]	0.000000	0.000000	0.000000

Images X, Y, Z represent the percentage of images with a relative geolocation error in X, Y, Z.

Georeference Verification

APPENDIX 12

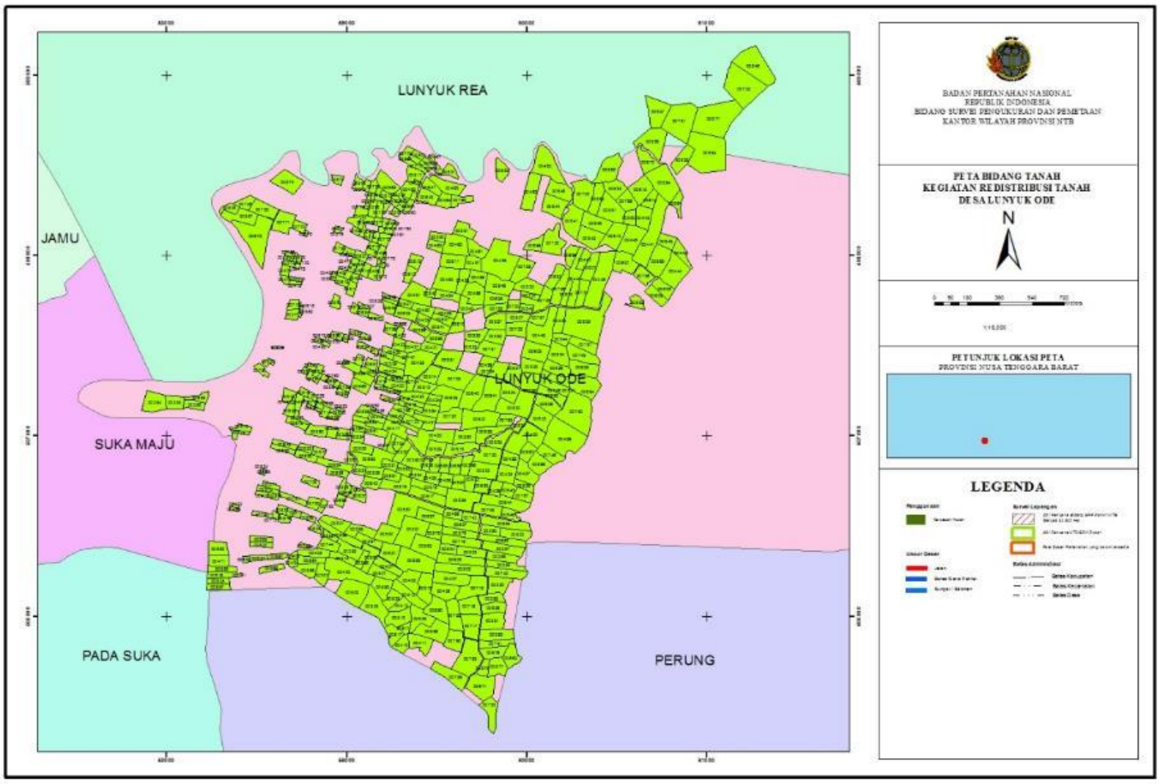
Interview Transcription (in Bahasa)

No	Question	Answers					
		Respondent-1	Respondent-2	Respondent-3	Respondent-4	Respondent-5	Respondent-6
1	Are you able to recognize your land parcel boundary from the image?	Yes	Yes	Yes	Yes	Yes	Yes
2	Is it easy or difficult to recognize your parcel boundary from the image?	Easy	Easy	Easy	Easy	Easy	Easy
3	In general, what do you think of the new approach?	Sophisticated	Sophisticated; Good	Very Good; Transparent	Good; Sophisticated; New	Good; Sophisticated; uncomplicate d	More sophisticated; vulnerable; easier; more flexible; simpler; faster; practical
4	How far do you feel about the land owners' involvement in the two methods						
	UAS Based Image Approach	4	4	5	4	5	5
	Existing method	4	4	4	4	4	5
5	How much the land owner was charged for the cadastral boundary measurement using existing method?	IDR 300,000	IDR 300,000	IDR 300,000	IDR 300,000	IDR 300,000	IDR 300,000
6	How long do you spend for the measurement using existing method?	< 1 hour, ±20'	Half day, ±12 hour	1 hour	5'	<30'	Can be whole day, depends on the weather
7	Regarding the accuracy of the output, what is your level of trust towards the two methods?						
	UAS Based Image Approach	5	4	5	5	5	5
	Existing method	4	4	4	4	5	5

8	Please mention any problems occur during the measurement (if any)	None	None	None	None	None	Problems when showing the boundary
9	Advice and remark regarding the new approach?	None	None	None	All the boundary are visible, we can see our neighbour's boundary also	None	Vulnerable regarding the boundary issues. Somehow promising to be very helpful, e.g. when the crops were very high, became problems during the direct survey.

APPENDIX 13

Parcel Boundary Map from Existing Approach (source: *Kanwil BPN NTB*)



APPENDIX 14

Budget Documentation from Existing Approach (source: *Kanwil BPN NTB*)

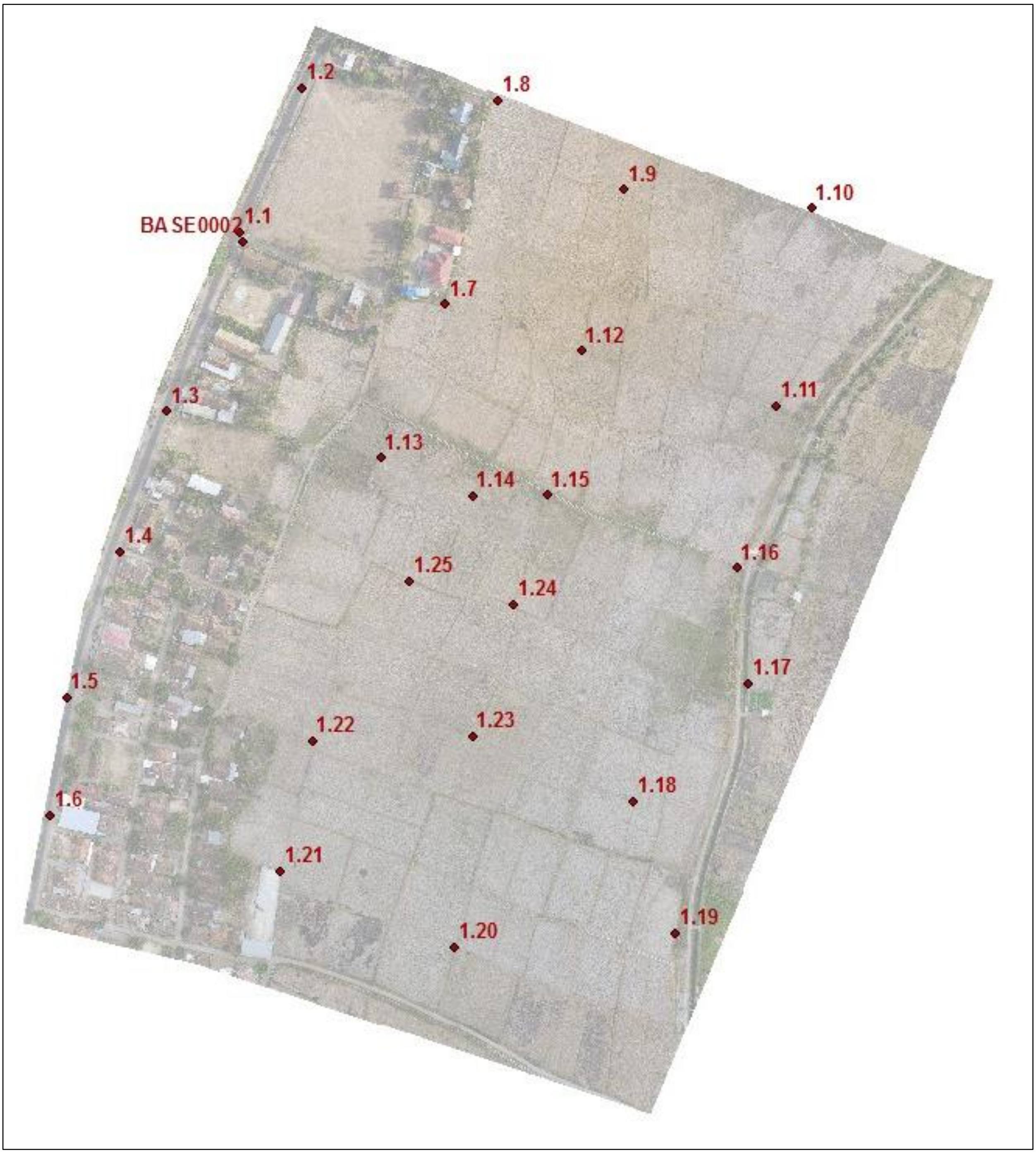
KODE	PROGRAM/ KEGIATAN/ OUTPUT/ SUBOUTPUT/ KOMPONEN/ SUBKOMP/ AKUN/ DETIL	PERHITUNGAN TAHUN 2013			KP/ KD/ DK/ TP	ALOKASI 2012
		VOLUME	HARGA SATUAN	JUMLAH BIAYA		
(1)	(2)	(3)	(4)	(5)	(7)	(8)
2999.050	Sertipikat Redistribusi Tanah Katagori II (23.00) NUSA TENGGARA BARAT	2,500 BIDANG		Rp 910,000,000		
012	PENGUASAAN TANAH OBYEK LANDREFORM (KEGIATAN USULAN PENEGASAN TOL)					
C	**PENGUKURAN DAN PEMETAAN KELILING DIKABUPATEN SUMBAWA**	2,500 BIDANG		Rp 212,500,000		
521211	*Belanja Bahan* (KPPN.038- M A T A R A M)	*50 Paket*	*Rp 350,000*	*Rp 17,500,000*		17.321.000
	Bahan	50 Paket	Rp 350,000	Rp 17,500,000		
	- ATK, Perlengkapan Teknis Lapang, Penunjang Komputer	50 Paket	Rp 350,000	Rp 17,500,000		
521219	*Belanja Barang Non Operasional Lainnya* (KPPN.038- M A T A R A M)	*50 Paket*	*Rp 3,900,000*	*Rp 195,000,000*		
	Biaya Pengukuran Lapang	50 Paket	Rp 2,700,000	Rp 135,000,000		
	- Biaya Koordinator Ukur (1 org x 1 Tim)	50 Paket	Rp 700,000	Rp 35,000,000		
	- Biaya Petugas Ukur (1 org x 1 Tim)	50 Paket	Rp 1,100,000	Rp 55,000,000		
	- Biaya Pembantu Ukur (3 org x 1 Tim)	50 Paket	Rp 900,000	Rp 45,000,000		
	Kontrol Kualitas Hasil Pengukuran Keliling	50 Paket	Rp 450,000	Rp 22,500,000		
	- Biaya Petugas Kontrol Kualitas	50 Paket	Rp 450,000	Rp 22,500,000		
	Biaya Jasa Perhitungan	50 Paket	Rp 375,000	Rp 18,750,000		
	- Pengolahan Data Lapang	50 Paket	Rp 300,000	Rp 15,000,000		
	- Koreksi Data	50 Paket	Rp 75,000	Rp 3,750,000		
	Biaya Jasa Penggambaran	50 Paket	Rp 375,000	Rp 18,750,000		
	- Pembuatan Peta Keliling	50 Paket	Rp 100,000	Rp 5,000,000		
	- Koreksi Peta Keliling	50 Paket	Rp 50,000	Rp 2,500,000		
	- Pengesahan Peta Keliling	50 Paket	Rp 25,000	Rp 1,250,000		
	- Pembuatan Peta Penggunanaan Tanah	50 Paket	Rp 75,000	Rp 3,750,000		
	- Pembuatan Peta Situasi dan Penunjuk Lokasi	50 Paket	Rp 75,000	Rp 3,750,000		
	- Pengesahan Peta Penggunanaan Tanah	50 Paket	Rp 25,000	Rp 1,250,000		
	- Pengesahan Peta Situasi dan Penunjuk Lokasi	50 Paket	Rp 25,000	Rp 1,250,000		
013	REDISTRIBUSI TANAH DI KABUPATEN SUMBAWA					
C	PENGUKURAN DAN PEMETAAN BIDANG TANAH	2,500 bidang		Rp 697,500,000		
521211	*Belanja Bahan* (KPPN.038- M A T A R A M)	*50 Paket*		*Rp 32,500,000*		
	- ATK, Perlengkapan Teknis Lapang, Penunjang Komputer	50 Paket	Rp 650,000	Rp 32,500,000		32.305.000
521219	*Belanja Barang Non Operasional Lainnya* (KPPN.038- M A T A R A M)	*2,500 Bidang*	*Rp 266,000*	*Rp 665,000,000*		
	Biaya Pengukuran Bidang Tanah	2,500 Bidang	Rp 266,000	Rp 665,000,000		
	Pembuatan dan Pemasangan TDT Orde 4	125 Tugu		Rp 43,750,000		
	- Biaya Pembuatan dan Pemasangan TDT Orde 4	125 Tugu	Rp 300,000	Rp 37,500,000		
	- Biaya Pembuatan Buku Tugu	125 Tugu	Rp 50,000	Rp 6,250,000		
	Pengukuran Bidang Tanah, Pengikatan TDT Orde 4 dan Pembuatan GU			Rp 506,250,000		
	- Biaya Koordinator Ukur (1 org x Tim)	2,500 BID	Rp 60,000	Rp 150,000,000		
	- Biaya Petugas Ukur (1 orgX 1 Tim)	2,500 BID	Rp 82,500	Rp 206,250,000		
	- Biaya Pembantu ukur (3 org x Tim)	2,500 BID	Rp 60,000	Rp 150,000,000		
	Kontrol Kualitas Hasil Pengukuran dan Pemetaan Bidang Tanah			Rp 115,000,000		
	- Biaya Petugas Kontrol kulaitas	2,500 BID	Rp 46,000	Rp 115,000,000		

Mataram, Januari 2014
KEPALA BIDANG SURVEI, PENGUKURAN DAN PEMETAAN
KANTOR WILAYAH BADAN PERTANAHAN NASIOANAL

Drs. I KETUT DIPTASARI, M.H.
NIP. 19601231 198503 1 022

APPENDIX 15

GCPs Distribution



APPENDIX 16

Fieldwork Limitations

Category	Limitations	Solution
External limitation	Weather constraints	▪ Gather local knowledge about the situation and weather ▪ Arranged plan based on the knowledge gathered ▪ Strict to the plan for image acquisition
	Limited time for field acquisition.	Arranged a good schedule and be discipline.
	Pilot's first time planning the unit	Spare an extra day to conduct a flight trial.
	Unavailability equipment to produce the imagery in the field	Use the available equipment and materials
	Equipment's battery/power constraints	Recharge after each flight and make use of available resources for emergency.
	Low number of participant during participatory boundary mapping and interview	Add extra information from the land staff involved and authorized party in the village who follow the procedure
	Imperfect quality of pre-markings caused placement difficulties during image processing	Selective sorting in using images to be processed, avoid using images with low quality visibility of the markings
	Community's unfamiliarity of map/aerial imagery reading	Brief explanation and assistance from author and local helper
Internal limitation	Author's inexperience in processing imagery using *Agisoft Photoscan*	Support and assistance from the expert of the private company
	Author's inexperience regarding conducting participatory boundary mapping and obtaining social data with interview.	Self-learning and ask support from local helper

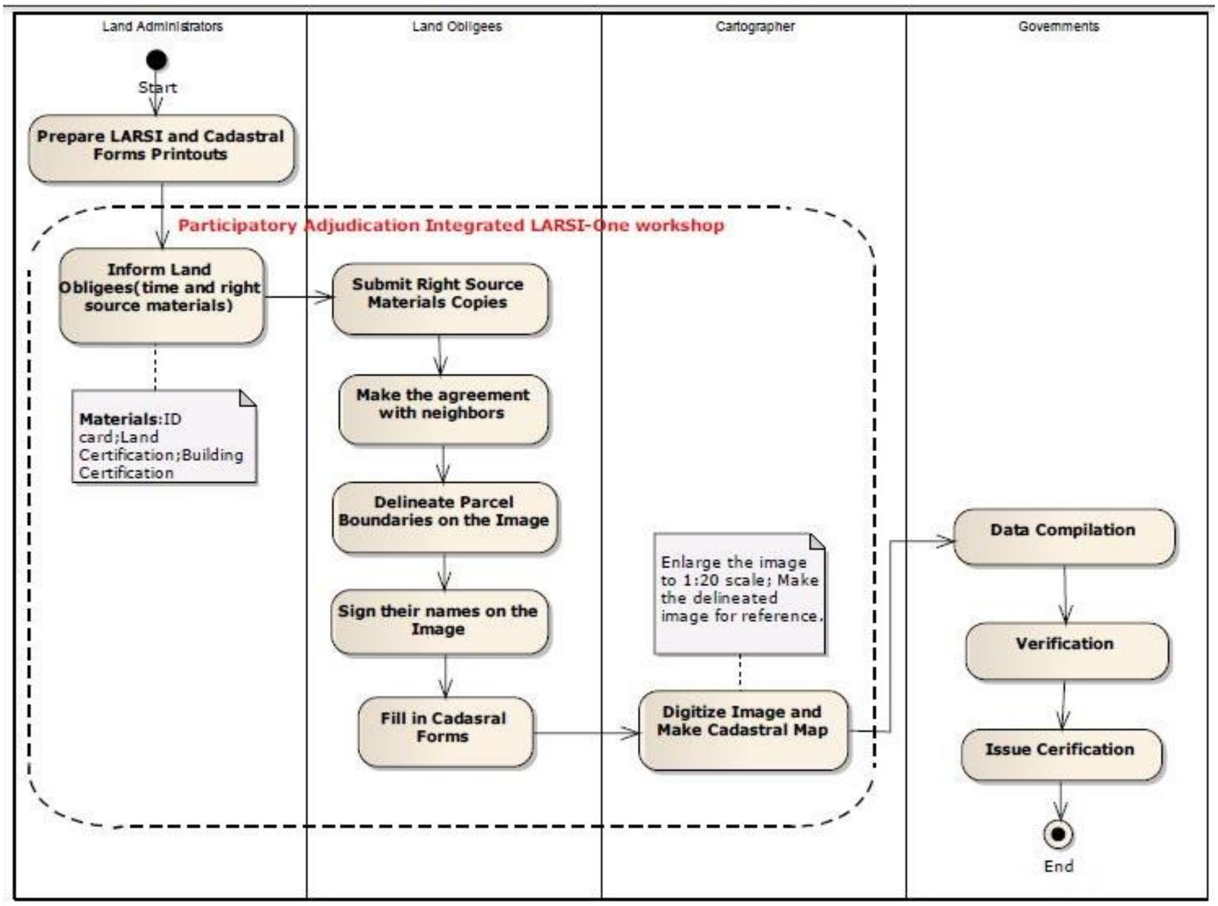
APPENDIX 17

Ethics Guidelines for Participatory Mapping

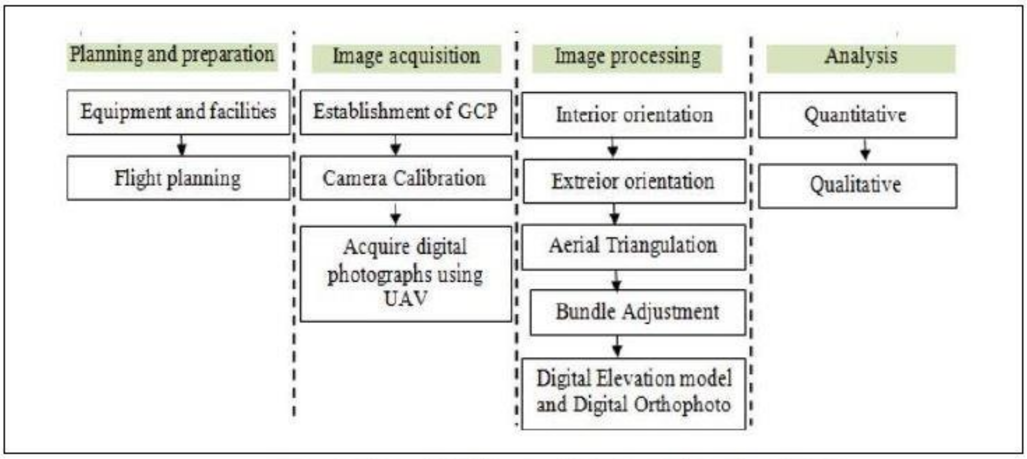
– Be open and honest
– Purpose: which purpose? And whose purpose? Be certain and clear about the purpose;
– Obtain informed consent;
– Do your best to recognise that you are working with socially differentiated communities and that your presence will not be politically neutral;
– Avoid raising false expectations;
– Be considerate in taking people's time;
– Don't rush;
– Invest time and resources in building trust;
– Avoid exposing people to danger;
– Be flexible;
– Consider using spatial information technologies that can be mastered by local people (or local technology intermediaries) after being provided sufficient training;
– Select spatial information technologies that are adapted to local environmental conditions and human capacities;
– Avoid outlining boundaries except if this is the specific purpose of the exercise;
– Do not sacrifice local perception of space in the name of precision
– Avoid repeating activities;
– Be careful in avoid causing tensions or violence in a community;
– Put local values, needs and concerns first;
– Stimulate spatial learning and information generation rather than mere data extraction for outsider's analysis and interpretation;
– Focus on local and indigenous technical management and spatial knowledge;
– Prioritise the use of local toponomy;
– Mapmaking and maps are a means and not an end;
– Ensure genuine custodianship;
– Ensure that the intellectual ownership is recognised;
– Be ready to deal with new realities which will emerge from the process;
– Observe the processes;
– Ensure that the outputs of the mapping process are understood by all those concerned;
– Ensure defensive protection of traditional knowledge (TK) or measures that ensure that IP rights over traditional knowledge are not given to parties other than the customary TK holders;
– If applicable, do your best to ensure positive protection of TK, or the creation of positive rights in TK that empower TK holders to protect and promote their TK.;
– Do not use the practice to support the forced displacement of people;
– Acknowledge the informants;
– Review and revise the maps;
– Examine international survey guidelines such as the AAA;
– Code of Ethic (www.aaanet.org/committees/ethics/ethcode.htm);
– Consider the GIS Code of Ethics (www.gisci.org/code_of_ethics.htm).

APPENDIX 18

Adapted Flowchart for UAS Based Image Approach



The Newly-Designed Adjudication Procedure from Jing, Y. (2011). *Assessing Larsi-Integrated Participation Procedure for Urban Adjudication in China*. Univeristy of Twente. Retrieved from http://www.itc.nl/library/papers_2011/msc/la/jing.pdf



Procedure of Ortho-photo Production using Digital Aerial Imagery from Udin, W. S., & Ahmad, a. (2014). Assessment of Photogrammetric Mapping Accuracy Based on Variation Flying Altitude Using Unmanned Aerial Vehicle. *IOP Conference Series: Earth and Environmental Science*, *18*, 012027. doi:10.1088/1755-1315/18/1/012027

APPENDIX 19

Elements of Spatial Data Quality and Fit-for-Purpose Land Administration

Elements of Spatial Data Quality (ISO 19157:2013):

Completeness	**Presence or absence of features, their attributes and relationships**
– Commission	Excess data present in a dataset
– Omission	Data absent from a dataset
Logical Consistency	**Degree of adherence to logical rules of data structure, attribution and relationships**
– Conceptual Consistency	Adherence to rules of the conceptual schema
– Domain Consistency	Adherence of values to the value domains
– Format Consistency	Degree to which data is stored in accordance with the physical structure of the data set
– Topological Consistency	Correctness of the explicitly encoded topological characteristics of a dataset
Positional Accuracy	**Accuracy of the position of features**
– Absolute/Ext. Accuracy	Closeness of reported coordinate values to values accepted as or being true
– Relative/Int. Accuracy	Closeness of the relative positions of features in a dataset to their respective relative positions accepted as or being true
– Gridded Data Accuracy	Closeness of gridded data position values to values accepted as or being true
Temporal Quality	**Accuracy of the temporal attributes and temporal relationships of features**
– Accuracy of a time measurement	Correctness of the temporal references of an item (reporting of error in time measurement)
– Temporal consistency	Correctness of ordered events or sequences, if reported
– Temporal validity	Validity of data with respect to time
Thematic Accuracy	**Accuracy of quantitative attributes and the correctness of non-quantitative attributes and of the classifications of features and their relationships**
– Non-quantitative attribute correctness	Correctness of non-quantitative attributes
– Quantitative attribute accuracy	Accuracy of quantitative attributes

Elements of Fit-for-purpose Land Administration:

Flexible	In the spatial data capture approaches to provide for varying use and occupation.
Inclusive	In scope to cover all tenure and all land.
Participatory	In approach to data capture and use to ensure community support.
Affordable	For the government to establish and operate, and for society to use.
Reliable	In terms of information that is authoritative and up-to-date.
Attainable	To establish the system within a short timeframe and within available resources.
Upgradeable	With regard to incremental improvement over time in response to social and legal needs and emerging economic opportunities.

APPENDIX 20

Cost Breakdown

1. Cost for Existing Approach using Terrestrial Method in IDR:

No.	Routine Operational/Recurrent Costs	Price per Unit	Volume	Unit of Measurement	Duration		Total Price	Description
1. 2.	Staff salaries (including social costs) Staff allowances (i.e. per diem, housing)	410,000	3	Person	2	day	2,460,000	According to Indonesian Corporate Association of Geospatial Information Survey and Mapping
3.	Purchase of capital equipment (i.e. IT software, hardware, survey equipment)							According to Indonesian Corporate Association of Geospatial Information Survey and Mapping
	– Total Station Rent	300,000	1	Unit	1	day	300,000	
	– Laptop Rent	50,000	1	Unit	1	day	50,000	
	– Software (GIS, mapping)	175,000	1	Package	1	day	175,000	
4.	Occupation expenses (i.e. building rents, utilities, etc.)			N.A.				Non-applicable - assumed non-exist
5.	Contract service			N.A.				Non-applicable - assumed non-exist
6.	Repairs and maintenance			N.A.				Non-applicable - assumed non-exist
7.	Vehicles and vehicle operation expenses							
8.	Materials and consumables							
	– Materials and transportation	266,000	1	Parcel	-	-	266,000	According to the State Budget of NTB Province in 2015
	– Consumption	13,000	1	Package	-	-	13,000	According to the State Budget of NTB Province in 2015
	– Boundary markers	300,000	1	Parcel	-	-	300,000	Derived from interview with the land claimants, 15-Sept-2015
	Total Cost per Parcel						**3,564,000**	≈ USD 264.12

2. **Cost for UAS Based Image Approach in IDR:**

No.	Routine Operational/Recurrent Costs	Price per Unit	Volume	Unit of Measurement	Duration		Total Price	Description
1.	Staff salaries (including social costs)	410,000	3	Person	2	day	2,460,000	According to Indonesian Corporate Association of Geospatial Information Survey and Mapping
2.	Staff allowances (i.e. per diem, housing)							
3.	Purchase of capital equipment (i.e. IT software, hardware, survey equipment)							
	– UAS rent	1,250,000	1	Unit	1	day	1,250,000	According to Indonesian Corporate Association of Geospatial Information Survey and Mapping
	– GPS RTK & receiver	950,000	1	Unit	1	day	950,000	
	– Laptop rent	50,000	1	Unit	1	day	50,000	
	– Software (GIS, mapping, GPS processing)	275,000	1	Package	1	day	275,000	
4.	Occupation expenses (i.e. building rents, utilities, etc.)			N.A.				Non-applicable – assumed non-exist
5.	Contract service			N.A.				Non-applicable – assumed non-exist
6.	Repairs and maintenance			N.A.				Non-applicable – assumed non-exist
7.	Vehicles and vehicle operation expenses	436,000	1	Project	-	-	436,000	According to the State Budget of NTB Province in 2015 and the author's record during field data collection
8.	Materials and consumables	670,000	1	Project	-	-	670,000	
	Total Cost for 5 parcels						**5,391,000**	
	Total Cost per Parcel						**1,078,200**	≈ USD 79.90

Note:
- The staff salary is the approximation of $Person\ Day\ Rate\ = (Person\ Month\ Rate\ /22\ ) \times 1.1$, where Person Month Rate for surveyor/operator level 1 is IDR 8,400,000;
- One working days is assumed to be 8 hours, therefore duration for the salaries is 2 working days. E.g. 900 min is 1 day 7 hours ≈ 2 days;
- From the interview in 16-Sept-206 with the surveyors of BPN, Total Station (TS) is the most frequent equipment used for the boundary survey in Indonesia. Therefore the calculation used for existing method is in the case of TS usage;
- Point 4, 5 and 6 are assumed as non-exist therefore it is marked as non-applicable (N.A.);
- The breakdown calculation price for the Cost of UAS Based Image Approach was done for 5 parcels.
- Currency conversion IDR 1.00 = USD 0.0000741884 retrieved February 10, 2016, from http://www.xe.com/currencyconverter/convert/?Amount=1&From=IDR&To=USD