Implementing Remote Sensing and Drone Mapping Technology for Land Management in Indonesia's Boundary Zone

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Key Words: border, land management, drones (unmanned aerial vehicle), remote sensing, government paradigms, acceleration of sustainable development.

SUMMARY

Indonesia is an archipelagic state, which has border with other states on the land, sea, as well as on the air. In the sea, Indonesia has direct borders with 10 countries, namely: India, Malaysia, Singapore, Thailand, Vietnam, Philippines, Republic of Palau, Australia, East Timor, and Papua New Guinea. As for the land, Indonesia has direct borders with 3 countries, namely Malaysia, Papua New Guinea and Timor Leste.

As we know, Indonesian people who live in boundary zone are generally in poor conditions with lack of public services, such as: social, transportation and education service and facilities. However, the changing of government paradigm in the last two decades has prompted greater attention to this area. Recently, various government programs are driven to the border region, notably in provinces that have land borders, that is West Kalimantan, East Kalimantan, East Nusa Tenggara, and Papua Provinces.

This paper will present about the land management programs in general which carried out in the Indonesia's border area, for example in Entikong, Sanggau Regency, West Kalimantan Province, and Motaain, Belu Regency, East Nusa Tenggara Province. The main focus in this paper is the using of remote sensing and drones or unmanned aerial vehicle (UAV) data for supporting those programs. Furthermore, by promote the cooperation with other agencies and encourage community participation in the border zone, those programs can be succeeding in result. The conclusion of the study shows that the utilization of drones and imagery data is the key point of innovation in land management program in order to support the acceleration of sustainable development in the border region.

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1. BACKGROUND

The usage of satellite imagery for many purposes is not new in Indonesia. This has been started since 1980's, primary in order to fulfill the government's need in making maps. Nowadays satellite imagery has been used to the broader applications such as transportation, weather monitoring, natural resources research, etc. Particularly in Land Management, satellite imagery is used as a base layer for creating land base map for land registration, and creating thematic map of land use, land potency, and many other related themes.

In recent years, another map-making technique, well known as drone or Unmanned Aerial Vehicles (UAV), has emerged in Indonesia. By using a certain camera that can mount to the UAV, the picture of the earth surface from a limited height can be produced. Just like aerial photograph concept, the obtained picture then be processed by using software in order to gain the required cartographic standard for making map.

In Indonesia this technique has been used for various aims such as village's area and potency mapping, city area mapping, tax potency mapping, infrastructure mapping, watershed mapping, forest and mangrove mapping, etc. A phrase "Drone for Villagers" has been discoursed and promoted by the government, to encourage several villagers in Indonesia, particularly to create paddy field mapping in their own village.

Even though UAV mapping technology has been widely used in Indonesia and still evolves for the next couple years, until now its implementation in land management area is not yet so far established. This situation is not supposed to occur, as the usage of this technique probably will give benefit for land management institutions. So, it becomes important for land management institutions to explore the advantages offered by this technology to help them execute their programs. In this paper, we explore the advantages of using UAV for mapping technique in order to support land management programs.

The advantages will be explained by first, analyzing the gap between the needs and availability of land base maps in Indonesia. Second, looking at the advantages of using drone for mapping technique to close the gap by exercising a simple advantages and disadvantages analysis from two border areas (Entikong, West Kalimantan, dan East Tasifeto, East Nusa Tenggara) that are planned for agrarian reform program as samples, and finally add the conclusion.

2. AGRARIAN PROGRAMS IN BOUNDARY AREAS

During last decade, the development in boundary areas gets a serious attention by the government. The shifting paradigm that put boundary region as nation display-window has push-forwarded every development sector related to the areas. This new mindset has been strengthened by the vision and mission of the government by promoting development from the outermost region. Indeed, this aims should be embodied by tremendous efforts of every involved stakeholders, including Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN). This effort can be shown by boosting agrarian programs on these areas.

Under Indonesian Mid Term Development Planning 2015-2019, ATR/BPN has been mandated to carry out Agrarian Reform in all Indonesia land territory. Agrarian Reform on Indonesian context basically is the combination of simultaneously asset reform and access reform program. Asset reform is considered as the government effort to redistribute land parcels to the landless farmers or small farmers who need land, and also by providing legal certainty to the land owner by registering their rights. Access reform can be defined as the government effort to support people to produce something from their land, by organizing and training the people, linking them to the capital provider and market, and also building infrastructure needed. Generally, Agrarian Reform intends to decrease the imbalance of land ownership all at once increasing the people's prosperity.

On the implementation of Agrarian Reform, there is a special condition that has to be considered. Generally, Indonesian land divides into forest area and non-forest area. Forest area covers almost 2/3 of Indonesian land area, while the rest assigned as non-forest area. Like in the non-forest area, in forest area there exist also people that become the subject of the agrarian programs. In the forest area, land registration can be executed only after the object, the land owned by people, if its status has been taken out from forest area. In order to do that, first there must be held an additional program called 'inventarisasi P4T' that are collecting and identifying data about subjects and objects in the forest area, as the basis for further process of expelling these area from forest area to non-forest area. On the other hand, the process of land registration on the non-forest area can be held directly without conducting 'inventarisasi P4T'. In short, agrarian reform program is implemented differently in forest area and in non-forest area.

Beside the process, another difference on conducting agrarian reform on these two locus can be seen by its object of interest. In the forest area, the objective of this program only can be applied on certain kind of land use, such as settlement, farming and plantation field. Dissimilar to this, in non-forest area the objective of this program covers all type of land use that existed. This makes the area that should be covered by the program would be varies from relatively narrow to larger area.

Regardless these differences, in both and in every step taken in the process, the availability of land base map is mandatory. Land base map, which is usually in the image format, can be used as the basis for mapping on the 'inventarisasi P4T' as well as on the land registration. Without the availability of satellite imagery, the representative land base map that needed for implementing this program cannot be expected.

3. AVAILABILITY LAND BASE MAP AND LAND MANAGEMENT IN INDONESIA

In the ATR/BPN's strategic planning 2015 – 2019, the focuses on land resources management are improving the efficiency of spatial and land resources planning, developing and strengthening the related regulations and law, and enhancing the availability of land base map up to 60 % of land area outside forest area. This planning emerges as a mandate of Nine Priorities Development Agenda (Nawacita), which was initiated by the President.

The fourth agenda of Nawa Cita declared obviously that the state should exist to reform system and law enforcement corruption-free, dignified and reliable. In addition to land management program, the agenda will ensure legal certainty of land ownership by realizing:

- Coverage of land base map up to 60% from land area outside forestry area;
- Coverage of land cadaster map up to 70% from national land area and;
- Coverage of land base map for supporting Spatial Detailed Planning among 1.931 locations

According to data, in 2015, Directorate of General Agrarian Infrastructure, responsible to establish and provide land base map in ATR/BPN, has produced land base maps of 38.598.799 hectares in various scales. The number is approximately 20,2% compared to the total of land area of Indonesia which is about 191 million hectares. Using 2015 data, which was the starting point to build land base map in large scale, total produced land base map is about 15.335.000 hectares or 22,88 percent from the total area of land outside forest area.

3.1. Data Imagery and Land Base Map Collection

In order to meet the demand about land-related data, ATR/BPN is responsible for formulating, determining and implementing institutional policy of agrarian infrastructure. Clearly then that one main purpose of the ATR/BPN is providing land spatial data. Various technique and technology have been implemented in regards with this task; aerial photography and satellite imagery mapping are widely used by ATR/BPN to produce land base maps.

During last two decades, remote sensing plays a strategic role for developing land base map in Indonesia. As well known, in the past, its mapping was largely based on low to moderate spatial resolution data such as Landsat TM and ETM, SPOT and IKONOS. However, due to their low spatial resolution and accuracy, these remote sensing data barely fulfill the precision and accuracy standard of land registration map for land legalization programs. Fortunately, recently the availability of high-resolution satellite imagery is increasing such as the ones from Digital Globe Aerial Imagery and Multispectral data, which makes possible to produce large scales of land base map.

3.2. Data Collection Before President Decree No. 6 of 2012

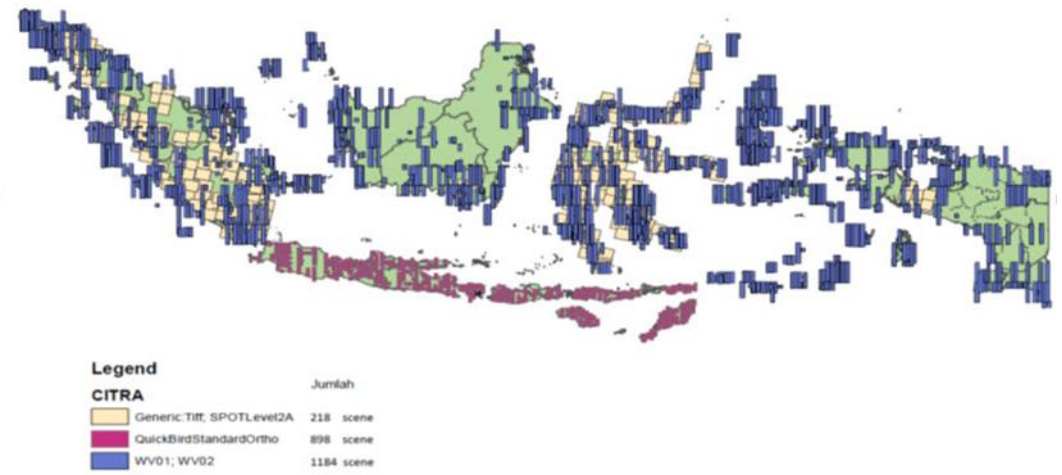

Figure 1. Satellite Imagery Collection from 2006 to 2012.
Source: Authors.

Before 2012, each government institution in Indonesia can procure high-resolution imagery data. From 2006 to 2012, Directorate of Basic Mapping had been collected imagery data separated from low, medium and high resolution such as Spot, Ikonos, Quick Bird and Global Base Map. The total area of these imagery data can be shown in Figure 1 and Table 1.

Table 1. Collection of Satellite Imagery Collection from 2006 to 2012

No	Imagery Collection	Year of Collection and Area of Collection (in Thousand Hectare)								Total
		Until 2006	2007	2008	2009	2010	2011	2012	2013	
1	High Resolution									
	a. Aerial Photogrammetry	2,8312	150	0	0	0	0	0	0	2.981,2
	b. Satellite Imagery (Quick Bird)	1.490,825	10.000	120	0	900	0	0	0	12.510,825
	c. Satellite Imagery/Global Base Map (World View 1 & 2)	0	0	0	0	0	53.000	0	0	53.000
2	Medium Resolution									
	d. SPOT 5	45.000.000	0	200	2.000	2.375	0	0	0	49.575
										118.067,025

Source: Authors

The table above shows that the procurement of satellite imagery took place from 2006 to 2011, and then stopped in 2012. This happened due to the President Decree Number 6 of 2012, which restricted and confined the procurement of satellite imagery only to two institutions, which are National Institute of Aeronautics and Space (LAPAN) and Geospatial Information Agency (BIG).

3.3. Data Collection After President Decree Number 6 of 2012

The regulation for other government institutions to acquire data from LAPAN or BIG has been issued by Minister of Treasury Republic of Indonesia Regulation Number 187/PMK.05/2014 about The Cost in Public Service Bureau of Center for Aerospace Technology Utilization in LAPAN. Based on this regulation, each government institutions including ATR/BPN could achieve data with no fee. However, it is often that the data which required were not available or suitable to the purpose of ATR/BPN. In consequence, some strategic programs on ATR/BPN cannot be supported by a sufficient spatial data of high resolution satellite imagery data. This condition takes effect to ATR/BPN in order to conducts their programs.

4. COMPARISON BETWEEN SATELLITE IMAGERY VS UNMANNED AERIAL VEHICLES

One of the main purpose of Directorate of Basic Mapping is to produce land base maps in high scale that cover 60% of non-forest area, or approximately around 67 million hectares. To fulfill the basic need of land base map, the availability of high satellite imagery data should be the first requirements. Although many types of satellite imagery are eagerly available, such as low resolution for free access in internet (Landsat, MODIS) and high resolution for purchase (World View, Pleiades, and Quick Birds), they are all occasionally cannot offer sufficiently high resolution, cover the specific area, or capture the time series, that are needed in order to fulfill the demand from larger area of interest.

On the other hand, there is alternative technique for mapping in order to meet larger area of interest. The using of unmanned aerial vehicles (UAV) or drones for mapping, recently is becoming a more pledge alternative. Mapping using UAV provides the opportunity to improve the speed and accuracy, as well as inexpensive cost of cadastral surveying and mapping.

4.1. Developing Land Base Map in Large Scale using Satellite Imagery

There are two types of satellite imagery data based on the sources for data collection; these are archive and multi-tasking data. In order to endorse the Fourth Agenda from Nawacita, in following 5 years, ATR/BPN should provide land base map both in large scale and also in massive area of coverage. As the one responsible for developing land and spatial planning policy within ATR/BPN, Directorate General of Infrastructure Agrarian is planning to develop not only land base map in large scale, but also thematic map in medium scale. Time plan to produce land base maps from 2015 to 2019 is shown on the table below.

Table 2. Planning For Emerging Land Base Map in Large Scale

Program	Action	Year				
		2015	2016	2017	2018	2019
To make land ownership certainty	Developing land base map and spatial detailed planning map in large scale.	15,3 million Hectares; 75 locations	8,5 million Hectares; 75 locations	10,8 million Hectares; 75 locations	13,8 million Hectares; 75 locations	18,4 million Hectares; 75 locations

Source: ATR/BPN's strategic planning 2015 – 2019

One aspect to be considered is that all processes about developing land base map in large scale using satellite imagery is dependent by the characteristic of the data itself. The satellite characteristics is including the variety of satellite imagery data, procedure, image resolution, minimum coverage, and budget estimation, as shown on the table below.

Table 3. Characteristics of Satellite Imagery that used for Large Scale Mapping.

Types of Image	Procedure Toward	Image Resolution	Minimum Coverage (KM^2)	Budget Estimation
High Resolution (World View 1,2 &3), Quick Bird, etc	Procurement	0.5-06 meters	Least coverage: 25 for archive; 100 for multi-tasking	Archive: ± 13 USD /Hectare; Multi-Tasking: ± 22 USD /Hectare)

Source: Ministry Treasury Regulation Republic of Indonesia Number 187/PMK.05/2014

4.2. Developing Land Base Map in Large Scale using UAV (Drones)

Another alternative for creating large-scale land base map is using unmanned aerial vehicles (UAV) or drones. UAV can be defined as "a powered aircraft system that is remotely piloted, either manually or semi-autonomously by remote control or autonomously through the use of on board computer navigation system or a ground control station that sends commands wirelessly to the aircraft" (Bailey, 2012). Recently, people use drone because it can create map more accurately, necessarily, automatically, and more competitively in budgeting. As the model of a drone varies, so does the type of camera or sensor to take image or information of earth surface. Standard imaging equipment on board consists of a digital camera and a multispectral sensor. As drone variously in weight, their flight time also differs depending on the fuel capacity (Papilaya, 2015). UAVs are potentially used for mapping areas that are not covered by satellite imagery. The table below shows UAV mapping characteristics.

Table 4. Characteristics of Mapping by Using UAV.

Types Drones	Coverage Needed (KM^2)	Procedure Toward	Image Resolution	Minimum Coverage (KM^2)	Budget Estimation
Close Range	Depends on requirement	Procurement or Self-Managing	10-40 Cm	0-10	1-10 USD /Hectare

Source: interviews with practitioners.

5. ANALYSIS

5.1. Observation Location

As mentioned before, there are two boundary districts that used as observation location which are Entikong and East Tasifeto. Both of these locations had similarly characteristics. First, they were

located on boundary area. Second, both were divided on to forest area and non-forest area. Third, each of them were divided in to several villages.

Figure 2. Location of Entikong and East Tasifeto.

5.1.1. Entikong District

Entikong is located in Sanggau, a regency in West Kalimantan Province. This district can be reached from Pontianak, the capital city of West Kalimantan by road trip in about 5 hours. Entikong is adjacent with Serawak State, Malaysia. There is a border crossing post between Indonesia and Malaysia in this district. Entikong is devided into 5 administrative villages, namely Entikong, Nekan, Palapasang, Semanget, and Suruh Tembawang. The total area of Entikong is 64.884 hectares which consist 54.438 hectares of forest and 10.446 hectares of non-forest area. The land use majorly consist of forests, farmlands, settlements, and shrubs. The distribution of these categories can be seen in Figure 3 and the proportion in Table 4 below.

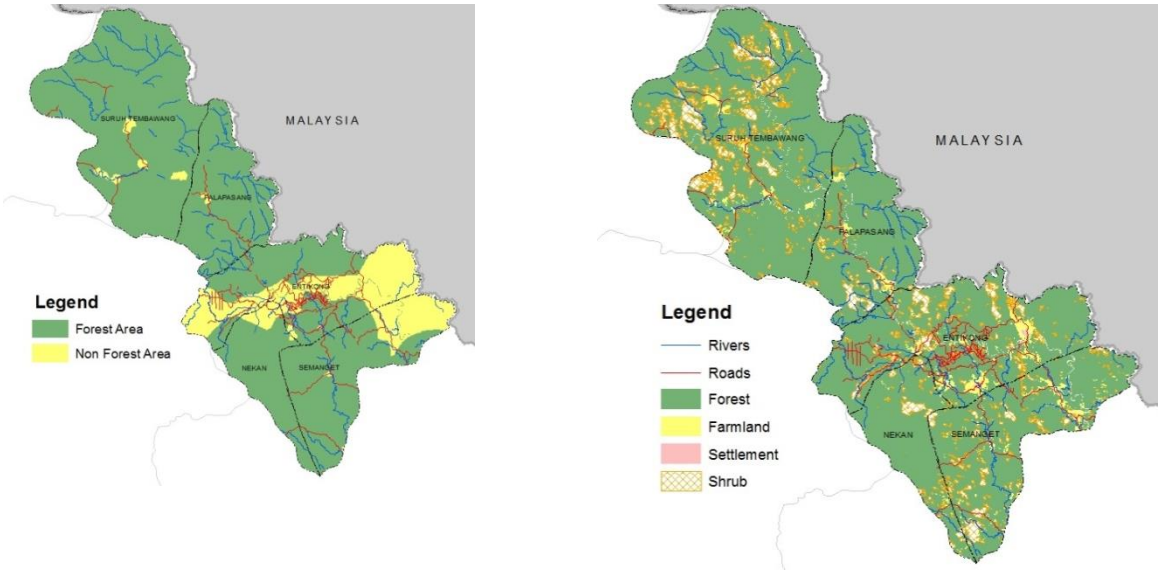

Figure 3. Area Status in Entikong District (left) and Land Use of Entikong District (right).
Source: Data of Forest Area 2015, Ministry of Envirionment and Forestry; Land Use Data 2011, Directorate of PWP3WT, Ministry of Agrarian Affairs and Spatial Planning/National Land Agency.

Table 4. General Description of Entikong District by Area.

No	Village	Forest Area (Hectares)	Non-Forest Area (Hectares)	Total Area (Hectares)
1	Entikong	8257	6635	14892
2	Nekan	5230	616	5846
3	Palapasang	9480	68	9548
4	Semanget	9376	2666	12042
5	Suruh Tembawang	22095	461	22556
	Total	54438	10446	64884

Source: Administrative Spatial Data 2010, Central Bureau of Statistics; Analysis Results.

5.1.2. East Tasifeto District

East Tasifeto District is located in Belu Regency, Province of Eastern East Nusa Tenggara. This district can be reach from Kupang, the capital city of the Province by road trip in about 12 hours. East Tasifeto adjacent with Republic Democratic of Timor Leste. There is a border crossing post between Indonesia and Timor Leste at Motaain in this district. East Tasifeto devided in to 12 administrative villages namely, Bauho, Davala, Fatuba'a, Halimondok, Manleten, Sadi, Sarabau, Silawan, Takirin, Tialai, Tulakadi, and Umaklaran. The total area of East Tasifeto District is 20.892 hectares which consist of 2.888 hectrares forest area and 18.004 hectares non-forest area. The land use of East Tasifeto majorly consist of forest, shrub, praire, settlement, and paddy field. The area distribution of these categories can be shown in Figure 4, as the proportion area can be shown in Table 5 below.

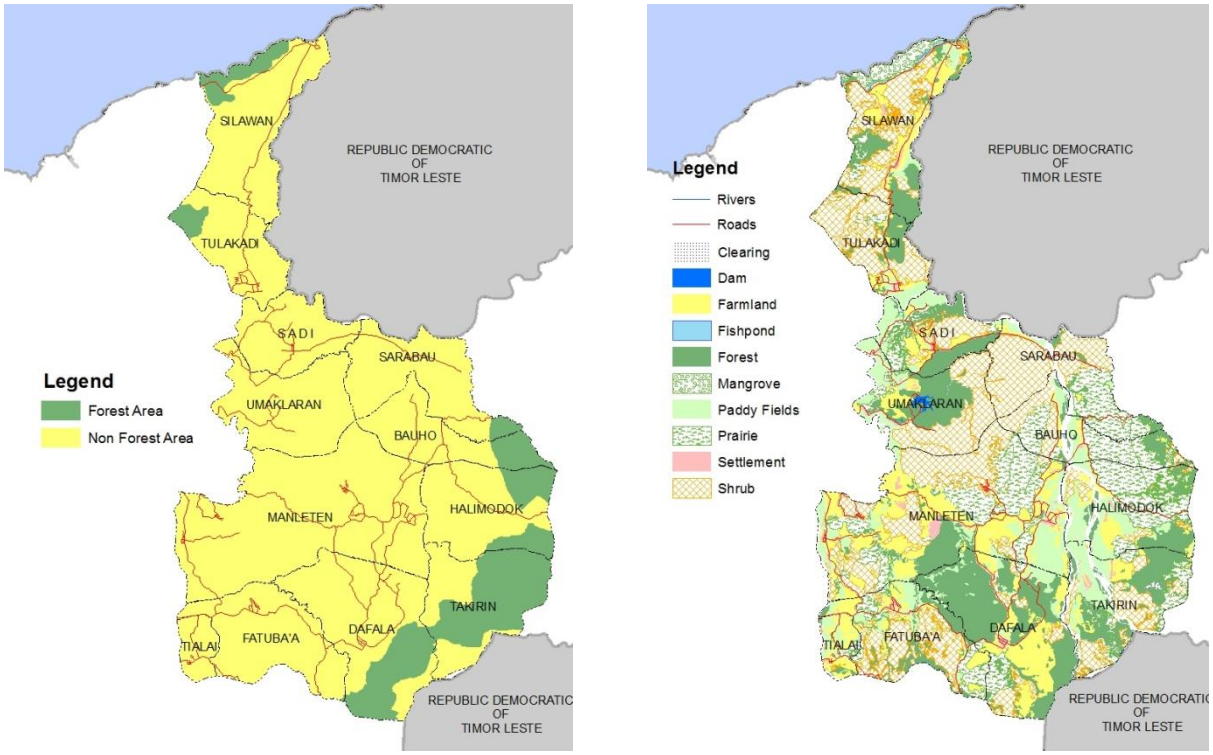

Figure 4. Area Status in East Tasifeto District (left) and Land Use of East Tasifeto District (right). Source: Data of Forest Area 2015, Ministry of Envirionment and Forestry; Land Use Data 2011, Directorate of PWP3WT, Ministry of Agrarian Affairs and Spatial Planning/National Land Agency.

Table 5. General Description of East Tasifeto District by Area.

No	Village	Forest Area (Hectares)	Non-Forest Area (Hectares)	Total Area (Hectares)
1	Bauho	232	897	1129
2	Dafala	642	1849	2491
3	Fatuba'a	2	1654	1656
4	Halimondok	436	1284	1720
5	Manleten	0	4336	4336
6	Sadi	0	1096	1096
7	Sarabau	82	1511	1594
8	Silawan	267	1711	1978
9	Takirin	1096	655	1751
10	Tialai	0	339	339
11	Tulakadi	130	1041	1171
12	Umaklaran	0	1632	1632
	Total	2888	18004	20892

Source: Administrative Spatial Data 2010, Central Bureau of Statistics; Analysis Results.

5.2. Community/Individual Ownership of Land in Forest Area.

As mentioned before, even though some areas of these two district are classified as Forest Area, but in reality, there are also community or individual land ownership inside the location. This ownership usually characterized by human-used area, such as settlement, farmland, paddy field, and many other. By comparing status and land use data, information about community or individuals ownership on these locations can be generated, as shown in Figure 5 below.

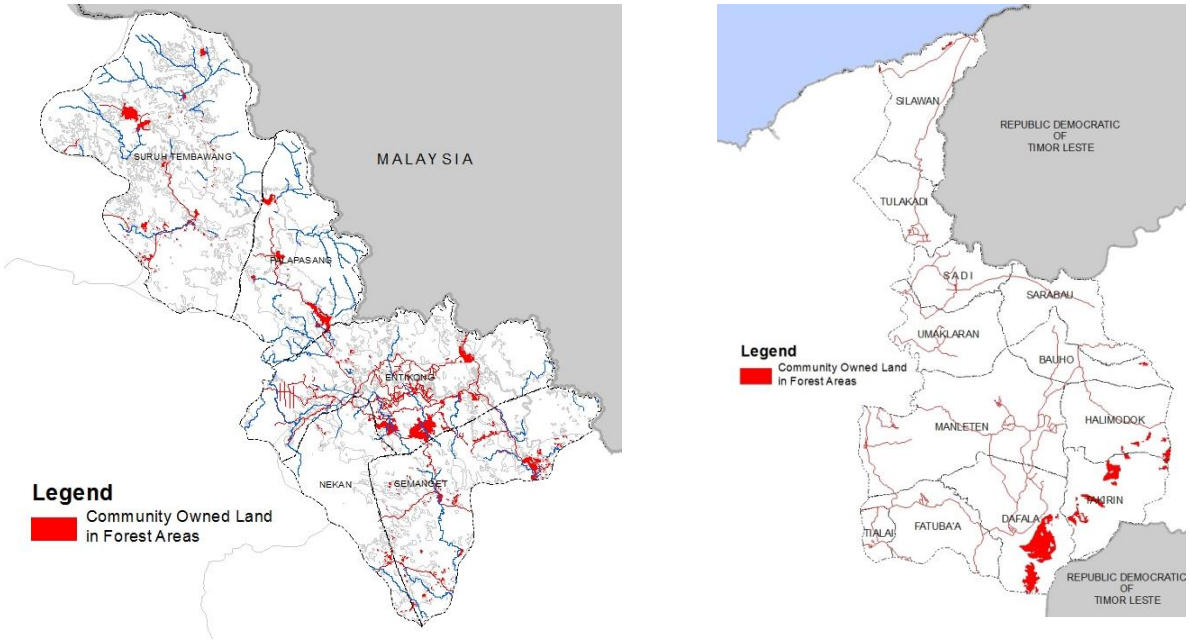

Figure 5. The Possibility Area Which are Owned by Communities or People inside Forest Area in Entikong District (left) and East Tasifeto District (right).
Source: Analysis Results.

The pictures above show the possible sites indicating collective and individuals' ownership of land inside the forest area in Entikong District and East Tasifeto District. As it seen, these possibly sites, which is marked by red dot, are spreads across these districts randomly. Even in each village, these possibly sites are on separate locations, where each of them are in relatively small size areas. The size of possible community or individuals land ownership inside the forest area in Entikong District and East Tasifeto District can be shown in Table 6 below.

No	Village	Possibly Land Ownership by Community or Individuals in the Forest Area (Hectares)	No	Village	Possibly Land Ownership by Community or Individuals in the Forest Area (Hectares)
Entikong District			East Tasifeto District		
1	Entikong	510	1	Bauho	4
2	Nekan	43	2	Dafala	254
3	Palapasang	222	3	Fatuba'a	0
4	Semanget	317	4	Halimondok	31
5	Suruh Tembawang	326	5	Manleten	0
	Total	**1418**	6	Sadi	0
			7	Sarabau	0
			8	Silawan	6
			9	Takirin	113
			10	Tialai	0
			11	Tulakadi	0
			12	Umaklaran	0
				Total	**408**

Table 6. Community or Individuals land ownership inside the forest area in Entikong District and East Tasifeto District. Source: Analysis Results.

As shown on the table above, the size of Possible Land Ownership by Community or Individuals in the Forest Area on each village are various between 4 hectares to 510 hectares. This figure will affect how the base map on this location would be made.

5.3. Comparing The Use of Satellite Imagery and UAV Mapping for Basemap

Creating land base map in order to conduct Agrarian Reform Programs need to take notices on the several matters. First, size of area to be covered in the map, since villages are various in size. Second, is the cost, while it would be better to have appropriate cost in providing land base map, retrenchment of government spending in Indonesia nowadays is also a significant issue that should be noticed. Third, the timing of procurement process in providing the maps is also important, as the program in Forest Area possibly held on the different time from its implementation in Non-Forest Area. Moreover, the latest the imagery data used for creating land base map, the more accurate it will present the existing land use of the location.

5.3.1. Cost and Coverage

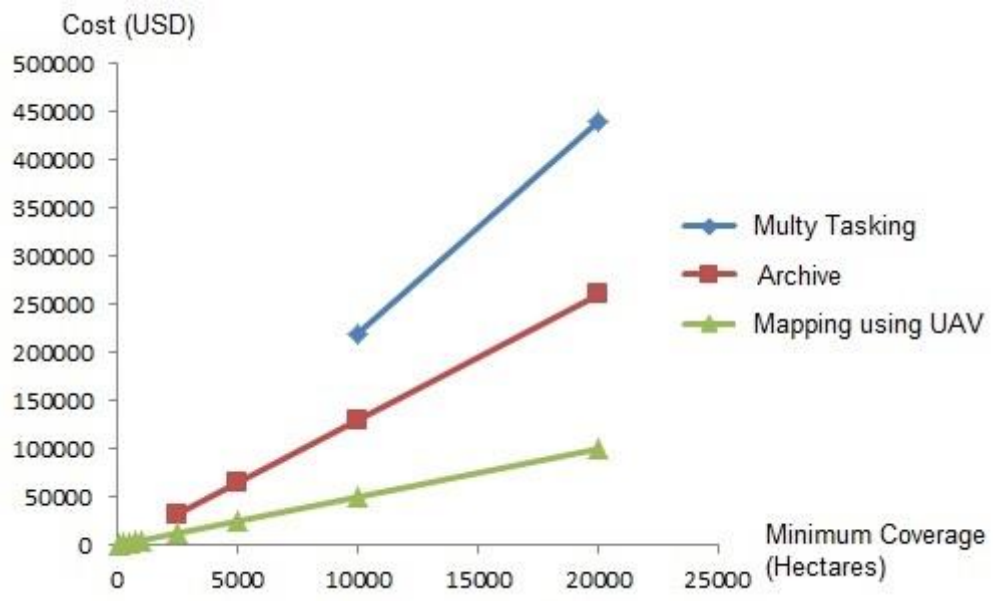

Figure 6. Cost and Coverage Analysis of Using Either Multy Tasking Satellite Imagery, Archive of Satellite Imagery, and Mapping using UAV. Source: analysis results.

By calculating standard prices of making land base map using three kind of resources such as multy tasking Satellite Imagery, archives of Satellite Imagery, and Mapping using UAV, the overall trends of cost for covering area can be plotted as shown in Figure 6 above. Multy Tasking Satellite Imagery can cover more than 10.000 hectares. The using of Satellite Imagery archive can cover with a minimum area of 2.500 hectares. Having this coverage, we can say that these first two options are not suitable for conducting small-area land base mapping. In contrast, the usage of UAV can be conducted at any covering area. So it can be used for small size area or relatively larger area. This flexibility is one of the advantages of using UAV.

5.3.2. Procurement and Timing

As mentioned before, Ministry of Agrarian Affairs and Spatial Planning/National Land Agency is no longer authorize to procure satellite imagery by itself. So in order to fulfill their own needs, it will takes longer times and procedures, as it will involving other institution. As a consequence, the ministry can no longer directly provide the needs of its provincial offices nor their land offices, this condition had made internal critics.

On the other hand, there is no regulation yet that limits the using of UAV for mapping. Moreover, there are many government institutions as well as private institutions are in the progress to implementing this technique for their own purposes. For example, many local governments are starting to use this technique for mapping. There are also many non-government agencies and

private commercial institution are now in the phase of developing the use of this technique for environmental, transportation, infrastructure, and many other purposes.

In order to show the differences of procurement process by times and procedures, the graph below (Figure 7) show the comparison between three alternatives process that can be done in order to make a land base map. Alternatively, there are only three possible option which can be held by the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency for fulfilling the demand of land base map in Indonesia. The first alternative is requesting satellite imagery from other institution. This mode require requesting process that may takes a couple of months for the provider institution can installed the request on their procurement plans on following year. As the result, land base map can-not be creates right away on the same year. However, if the requesting process rejected for a reason that the satellite imagery of the requested areas had already available from the procurement process in the previous years, the satellite imagery can be taken directly and use for process.

The second alternative is procuring land base map using UAV by the third party. On this mode, the mapping process can be done in the same year as long as it had been planned in the Ministry Work Plans on previous years. However this mode is uneasy to be imply for a more tactical needs, such as if the location had to be switch over due to the changes in priority that can be happen for some reasons.

The last alternative is procuring land base map using UAV by self-managing. On this mode, a considerable effort would be needed be at the beginning, such as UAV procurement and human resources training. However, after it initial difficulty, this mode will provide a cheaper land base map making process, as well as, it will answers every tactical needs that sometimes used to occurs. This mode also gives the Ministry of Agrarian and Spatial Planning/National Land Agency to become more independent, especially on land base map making, which is one of its main task. In addition, the using of this mode surely provides the newest existing of land use, that usually rarely available and quite expensive.

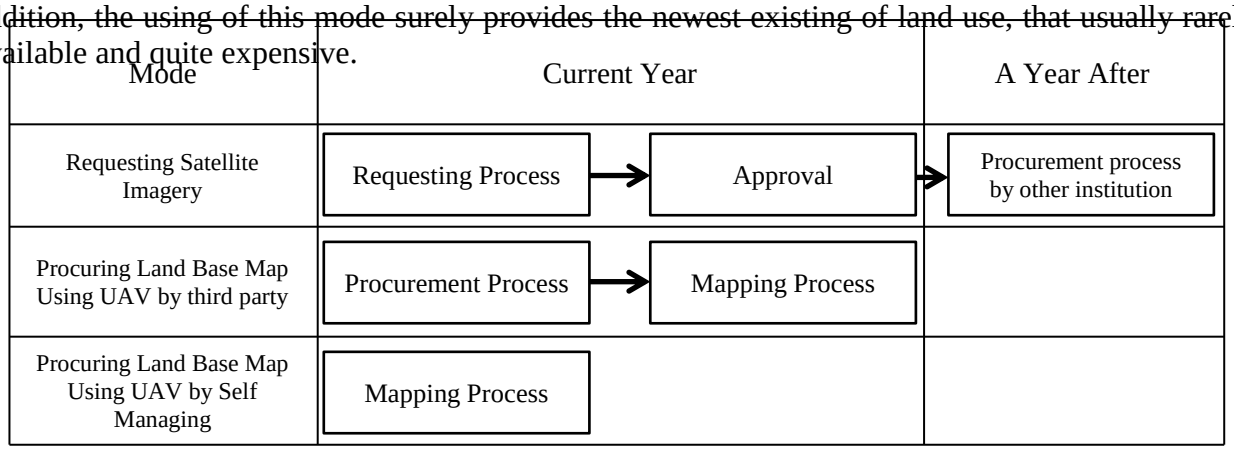

Figure 7. Land Base Map Making Procedures of 3 Different Procurement Modes.
Source: Authors.

6. CONCLUSION

In conclusion, UAV mapping technique will give several benefits for the users. First, it will be faster in producing land maps. Second, it can provide actual information about the existing land use. Third, it can be tactically conducted, so it will provide the ability to adjust the changing of location in a project almost immediately without facing any significant administrative obstacle. It can be conducted inexpensively, cheaper than using any other mapping technique. Fourth, it is independent in mapping scale of area coverage, especially on the small area. However, in order to implement this technique, we will need investment in infrastructure and human resources capacity building.

UAV is considerably a solution to support the Agrarian Reform Programs, which usually take place in various size or location of the intended areas, especially in the project location inside the forest areas. It will give significant impacts to the project, since high scale of satellite imagery on these locations were rarely found or procured. The use of this technology will shove the vacancy of spatial data which is needed and ease the burden that faced by many land office in order to produce maps.

Having the advantages of UAV mapping, the usage of available satellite imagery data should not be ruled out. Combination of both techniques even offer greater advantages. The satellite imagery is relevant to the area which has not significant land use changes for a quite long period of time such in rural areas or in a less dense village, so it still can be used reliably in order to produce land base map. It means the use of combination of these techniques could be more efficient.

Finally, with increasing challenge to produce land base map in the following years, advocating the usage of UAV technique in ATR/BPN is getting more and more important. Directorate General of Infrastructure Agrarian as the responsible party shall promote the usage of this technique, by creates regulation and technical guidance to encourage Land Provincial Offices and Land Offices to apply this technique on the implementation of its duties.

7. ACKNOWLEDGEMENT

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