Application of Remotely Sensed Satellite Imagery for Village Boundary Mapping in Indonesia: Case study in Hulu Sungai Tengah Regency, South Kalimantan, Indonesia

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Key words: Pleiades, WorldView-2, and High Resolution Satellite Imagery

SUMMARY

Indonesia is a big country with 250 million people and spread over 34 provinces, 416 districts, 98 cities, 7,160 districts and 83,184 villages. The administrative boundaries of a village are very important to affirm and to stipulate legal aspect in the management of resources. The setting and affirmation of the village boundary is the embryo for the determination and affirmation of boundary at the upper administrative levels. It is important to establish and confirm the official village area and boundaries as an effort to prevent village boundary conflicts. Currently in Indonesia, many villages have already village boundary maps but they are not yet compatible with cartographic rules. Only a small percentage of villages have village boundaries in accordance with the Minister of Home Affairs Regulation No. 45 of 2016, an official guidelines for determining and affirming village boundaries. The objective of this paper is to discuss village boundary mapping using high resolution upright satellite imagery by cartometric method in Hulu Sungai Tengah Regency, South Kalimantan Province, Indonesia. Results of this study give the confirmation and determination of village boundaries. This method has proven accelerated the process of setting village boundaries. In this activity, the village boundary has been successfully mapped in 9 districts consisting of 127 villages. The results of this activity will become a complementary document to get the village boundary determination by other administrative agency. The problems faced in village boundary mapping are lack of human resources and the unavailability of high resolution upright satellite imagery. Differences of perception and lack of understanding of the community regarding the importance of determination and affirmation of boundaries and the lack of authentic evidence of the village boundaries becomes an other obstacle in the implementation of determination and affirmation the village boundaries.

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1. INTRODUCTION

Indonesia with a population of more than 250 million by 2015 (BPS, 2016) is the fourth most populous country in the world after China, India and the USA (Widiatmaka *et al*., 2016). The Indonesian territory compose of 34 provinces, 416 districts, 98 cities, 7,160 districts and 83,184 villages. Village is the smallest unit of government administration system in Indonesia but it plays importance role in the management of natural resources. As conveyed by actual President of Indonesia Joko Widodo, Indonesia's development strategy should be started from the village as well as from the border the country region. Consequently, village area is very important as the basis of development.

One of the problem in villages handling in Indonesia relate with the fact that there are no clear boundaries among villages as well as no legal basis for administration area. As a result, administrative processes at the village level, for example administrative processes related with amount of population, land registration, land taxes and others become obstructed.

Village Map is actually increasingly needed with actual Indonesian government policy to assist village development by providing village allocation fund. One of the indicator for allocated village fund is the size of village. To obtain the village area and size, a clear and firm village boundary map is so, very necessary. On the other side, there are still many of the 83,184 villages that do not yet have a village boundary map and so, the area of such village is not yet identifiable. For the village which already have map, most of them did not obey the cartographic rules. There are several reason for this: there are no detailed topographical maps (scale 1: 5000 at least), the existing village boundary map has no coordinates and so the geographic position could not be known and the delineation of the village boundary is given only in a sketch form, not a map. In other, there is no information about the data source of existing topographical map. As a result, the existing village map cannot be used for analyzing the size of village, the distance from other cartographic objects (such as road and district capital), as well as a real position against other areas. Due to the bad cartographic rules, the existing village map cannot help to solve the disputes of the village conflicts.

The Indonesian Law No. 6 of 2014 about the Village (Presiden RI, 2014) states that the village is a legal community unit that has territorial borders, authorized to regulate and administer government affairs. Village should also accommodate the interests of local communities which are based on community initiatives. The origins and/or traditional rights

in the villages are recognized and are respected in the system of government of the Republic of Indonesia. The regulation of the boundaries of the villages is confirmed by the Regulation of the Minister of Home Affairs No. 45 of 2016 about Guidelines for Determination and Affirmation of Village Boundaries (Indonesian Ministry of Home Affair, 2016). In such regulation, it is mentioned that the determination and affirmation of village boundaries aims to create good governance, providing clarity and legal certainty of the village that meets the technical and juridical aspects.

During the period of 2013 to 2017, Indonesian Geospatial Information Agency has made village boundary maps in some part of Indonesian territory. Totally, there are 12,159 villages from total of 83,184 villages (or about 15%) which have been mapped at scale of 1:5,000. The remaining of 85% are still up to now do not have a village boundary map at the scale appropriate (1: 5,000). There are many obstacles in making the village maps, such as unavailability of topographic maps at scale of 1: 5,000, lack of human resources in the field of geospatial information, as well as limited availability of ortho-rectified high resolution satellite imagery.

Indonesian Geospatial Information Agency is the responsible agency for providing the base map, including ones at a scale of 1: 5,000. However, due to the difficulty of realization, the agency has actually made efforts to provide village boundary map using cartometric method as well as high resolution upright satellite imagery instead of 1:5,000 topographical map. High resolution upright satellite imagery is a satellite imagery with spatial resolution of 0.50 m and so, it can be used for mapping at detailed scale. Pleiades, Geo-eye, WorldView, Ikonos and QuickBird are some of the satellite data that have spatial resolution equivalent to the level of accuracy of the base map scale of 1: 5,000 (Elaksher, 2009; Said, 2013; Jayaprasada, 2006). High resolution satellite images have been used for mapping village boundary (Rao *et al*., 2014; Budisusanto *et al.*, 2014).

Taking into account the importance of the village boundary map and concerning by the fact of limited number of existing village boundary maps, this study was conducted with the objective to study the village boundary map in a rural regency in Indonesia by applying an upright image of high resolution satellites images with cartometeric method. It is expected that the results of this study can increase the availability of accurate village boundary map.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Hulu Sungai Tengah Regency, South Kalimantan Province, Indonesia. Hulu Sungai Tengah Regency is the smallest regency of total 13 regencies in South Kalimantan Province. It covers an area of approximately 177.080 ha or 4.57% of the total area of the province (**Figure 1**). Geographically, the regency is located at position of 115°8’56.965” - 115°53’32.520”E and 2°27’5.213” - 2°46’54.559”S. Administratively, the region consists of 11 districts and 169 villages. The region lies on swampy area and from

lowland into the highland. The lowland part of this region is part of Central Kalimantan Lowland, while the highland part is part of of Meratus Mountain with the highest mountain is Mt. Gunung Besar (1,892 m a.s.l.). Indonesian island in a whole lie in active geologic plate tectonic, however the geology of this regency is out of the area of active plate tectonic, thus this regency is relatively stable from volcanic activities. Two main rivers which flows in the region are Sungai Batang Alai and Sungai Barabai. Both rivers are the main sources of water for all human activities including for drinking water.

Hulu Sungai Tengah Regency has a wet tropical climate that is characterized by high rainfall. According to Schmidt and Ferguson climate classification, the regency has a climate type B, with Q value of 32.14%. The daily air temperature ranges from 21.19ºC to 32.93º C. The average annual rainfall is 2,862 mm with the number of rainy days of 108 days.year^{-1}. The minimum rainfall of 102 mm is generally occurred in August while the maximum rainfall is 387 mm, which occurred on December. The highest amount of rainy days are occurred on December to March (12-14 days) while the lowest ones occurred on July to September (4-5 days). According to the Indonesian Central Agency on Statistics (Hulu Sungai Tengah Statistic Board, 2016), the population of Hulu Sungai Tengah Regency in 2016 was 263,000 inhabitants, with the population density of 149 people.km^{-2}. Hulu Sungai Tengah Regency is the most populous regency in South Kalimantan Province.

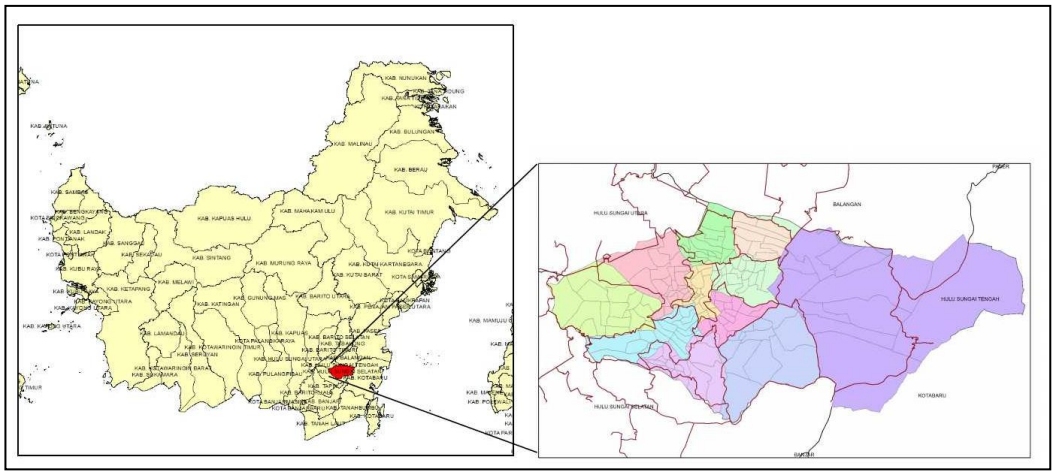

Figure 1. Situation map of the study area of Hulu Sungai Tengah Regency, South Kalimantan Province.

2.2 Materials

2.2.1 High Resolution Upright Satellite Imagery

High resolution upright satellite imagery applied in this study are Pleiades and WorldView-2. Unfortunately, these high resolution upright satellite imagery covered only 40% of the study area, while in the rest of the area, the imagery was unavailable (**Figure 2**). Pleiades is composed of two very-high-resolution optical earth-imaging satellites that provide the

coverage of earth's surface with a cycle of 26 days. Pleiades is composed by 50 cm panchromatic and 2 m multispectral (blue, green, red and near infrared) (Satellite Imaging Corporation, 2018). In this study, Pleiades record of August 11, 2013 was applied that covers 20% of the study area, while the rest of the area (20%) are covered by WorldView-2 image, taken at UTC time 2:59:52 AM on May 30, 2014. WorldView-2 was launched on October 8, 2009. It is the first high-resolution satellite with 8-Multispectral imaging bands. The spatial resolution of panchromatic imagery is 0.46 m, while multispectral imagery has a resolution at 1.84 m ((Land Info, 2018). In general, both satellite images were corrected first from geometric distortion. The input for geometric correction were Digital Elevation Model (DEM) and Ground Control Point (GCP). The DEM was derived from topographic map of 1:50,000. The total GCP and ICP used for geometric correction were 121 points, they are measured directly in the field using DGPS on 2016. All of the imagery processing was done by using PCI Geomatica software. The procedure of ortho-rectification are displayed in **Figure 3**.

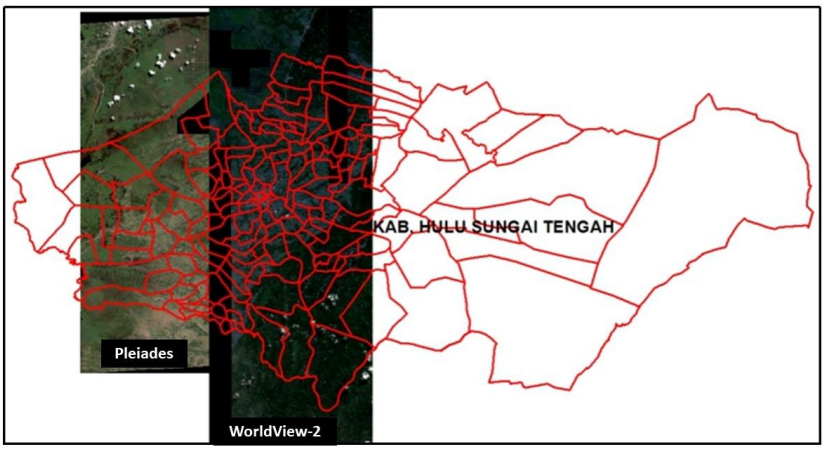

Figure 2. The coverage of high resolution satellite imagery of study area

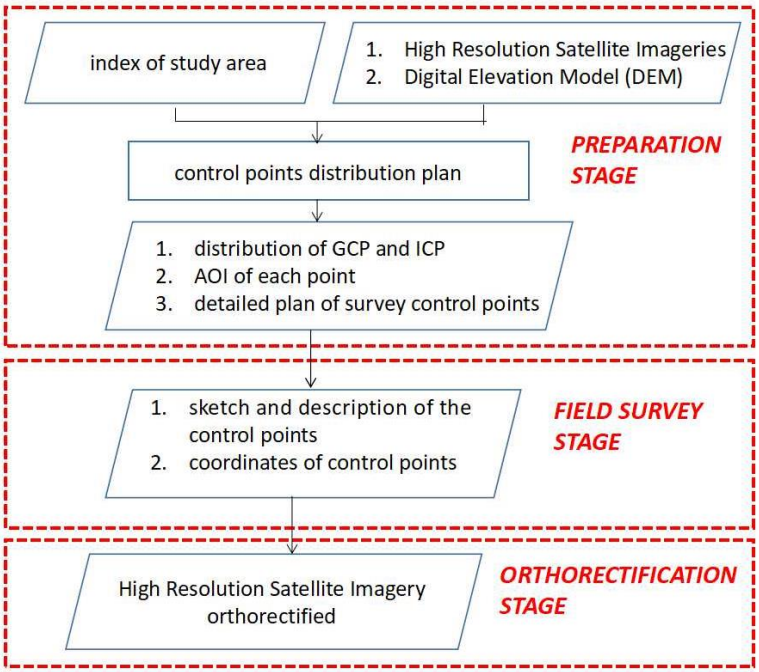

Figure 3. The Flow diagram of ortho-rectification processes

2.2.2 Topographical Map

The topographic map used in this study was the most detail scale and the newest one that is available in the region. The map is available at scale of 1:50,000 and was produced on 2013. The topographical map was composed of 8 layers and one of the layer is administration boundary. Since the scale of the map is too small for mapping village boundary, thus this map was used only for getting general view of administration boundary of the study area.

2.2.3 The Administration Boundary Map

The most recent digital data of the administrative boundaries used in this activity are as follows: (i) existing Administration Boundary Villages map, obtained from Hulu Sungai Tengah Regency and (ii) the village administration boundary from Center of Statistic Board (BPS, 2016). The tentative administration boundary map of study area was created from all existing administrative maps and are object of verification by administration agency, organized in a workshop for this research (**Figure 4**).

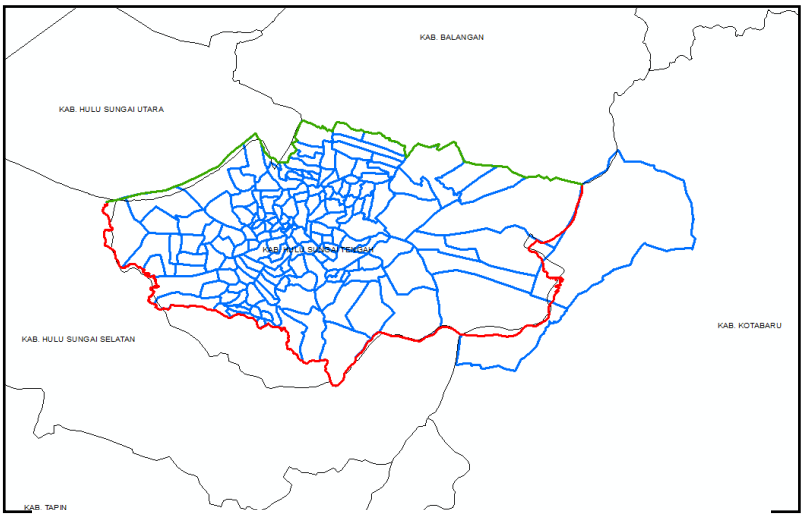

Figure 4. The administration boundary map of study area

2.3 Methods

This study used remote sensing technology and geographic information systems as well as delineation of administrative boundaries by cartometric method. In this case, the cartometric method used is tracking the boundaries on the working map as well as the activity of determining the points of coordinates of village boundaries (Riadi, 2015). Both activities were done in the field in workshop activities. In general, this village boundary mapping methodology is divided into three main stages: (i) preparation, (ii) workshop activities and (iii) processing of village boundary maps and map presentation. An explanation of the methodology is presented in **Figure 5**. All of the spatial process was done under ArcGIS 10.3. The preparation stage is carried out in the laboratory by conducting an analysis and creating a working map that will be used on workshop activities. In the next stage, a workshop was conducted by verification of village boundaries by asking the inputs from the village stakeholders. The result of the workshop activity is an agreed map, coordinate points, as well as agreement reports. The last stage of the activity was finalization of the map and agreement documents.

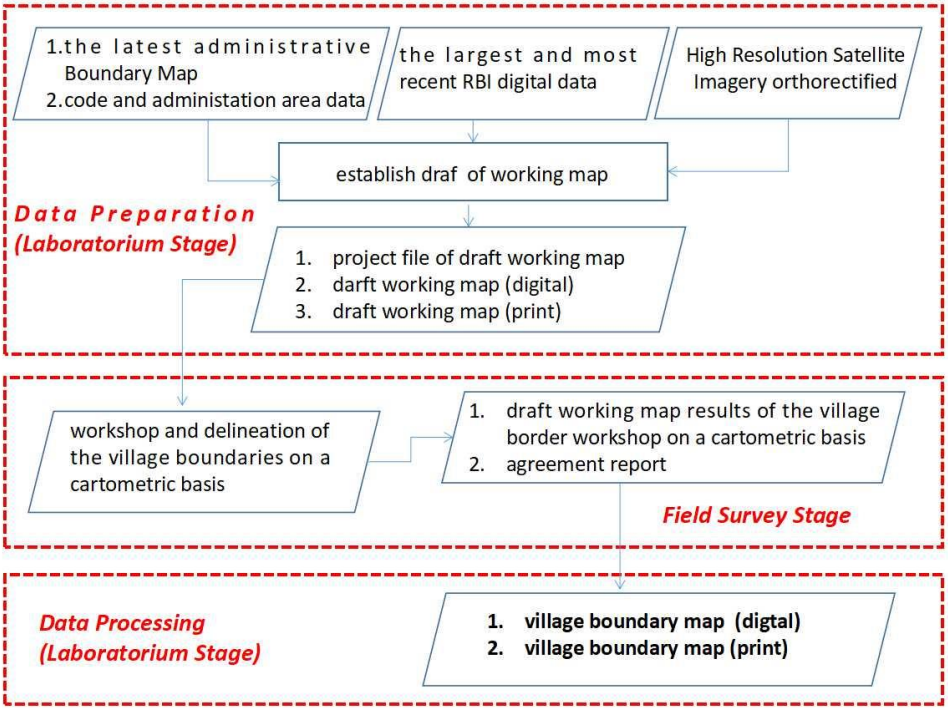

Figure 5. The flow diagram of village boundary mapping

3. RESULT AND DISCUSSION

Final Result. The study shows that mapping of village boundaries using high resolution upright satellite imagery and cartometric method has resulted in an accurate map. In other, mapping activities can be done quickly and inexpensive. In this study, high resolution upright satellite imagery has been used as the base data instead of topographical map. Consequently, the accuracy of village boundary map resulted depends on the quality of high resolution satellite imagery data used as well as quality of the ortho-rectification process.

The study indicated that Pleiades and WorldView-2 allowed an accurate estimation of the village boundary map with average horizontal accuracy of 1.62 meters. The input of ortho-rectification process were DEM which are derived from topographical map and 121 GCP. However, the accuracy of the boundary delineation depend also on the result of image interpretation done in the verification process in the workshop. The tentative village map produced in laboratory analysis stage was validated by stakeholders in the villages by interpreting the satellite imagery by using interpretation keys. The result of overlay between tentative village map with the final village boundary map is displayed on **Figure 6**. The unmatched between tentative map (working map) and the satellite imagery as well as the final village map were caused by the difference scale of data input and the satellite imagery resolution. In this research, the administration boundary map as an input data has scale less compared to the existing satellite imagery.

The final village maps which can be generated in this study are only 127 villages from 9 sub-districts, out of a total of 169 villages from 11 sub-districts in the Regency. There are a limitation of the area mapped, since tracking and positioning the village boundary line was done only in villages where upright high resolution satellite image data are available. The result of this study are village boundary map, and are displayed in **Figure 7**. The tentative village boundary map and the final boundary map are likely unmatched, this is due to the database of both village boundary which are differences. Another reason is that, some villages are divided and separated from the parent village.

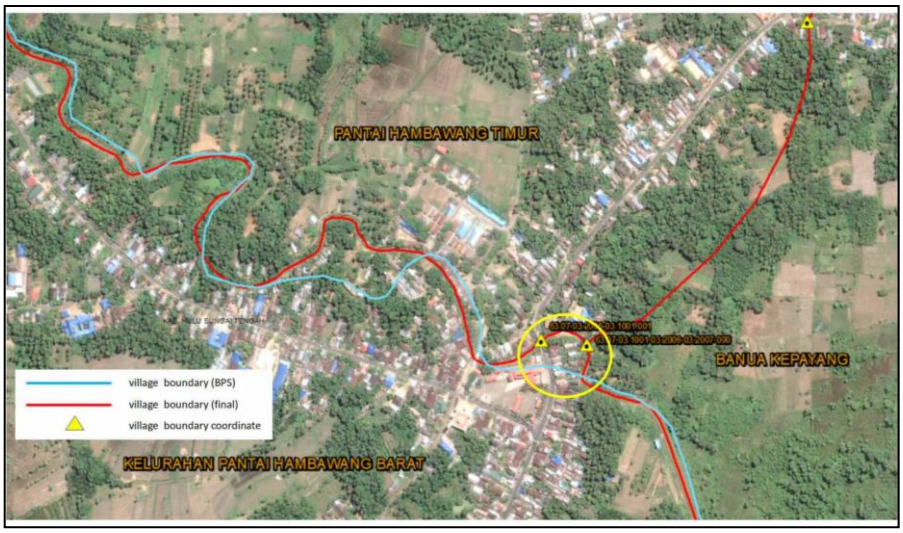

Figure 6. The overlay between boundary of tentatife village map within the boundary of final village and satellite imagery as a background.

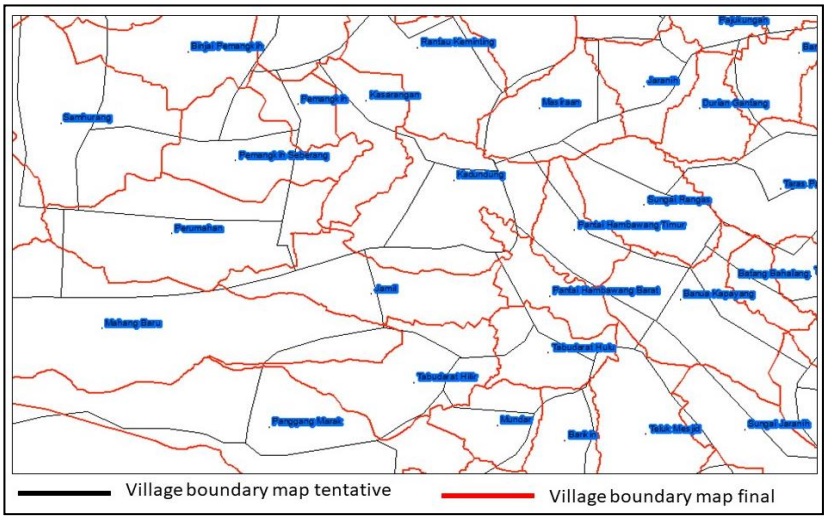

Figure 7. The overlay between tentative village boundary map and the final map

The workshops were held in the 9 district offices by presentation to all the stakeholders in each village. At this occasion the work maps are corrected and are clarifed by stakeholders. This process will determine the success of the correct village boundary map. In case of the village stakeholders were not present in the workshop, then there are no agreement on village boundaries delineated. In this workshop, an agreement on the determination of coordinate points in the bordering and mutually agreed areas are also implemented. At the end of each workshop, stakeholders sign the village boundary agreements, while coordinate points are marked by signatures and are sealed as proof of agreement. Coordination workshop and verification of village boundary maps are displayed in **Figure 8**. The output of this study is a final village boundary map and coordinate point, formalized by formal hand signature and stamps.

Figure 8. The workshop activities in the district office for discussing and verifying the boundary map

In this study, 370 boundary segment was agreed, from the initial number of 352 boundary segments. The number of segments are higher than the initial ones, this is due to the differences in the level of detail of geospatial data sources. The maps and documents produced in this study became the material to be the processed to become draft of Head of Distict's Regulation and finally to produce definitive village boundaries. The final result of this study were 127 villages boundary maps. The excample of this final map is displayed in **Figure 9**.

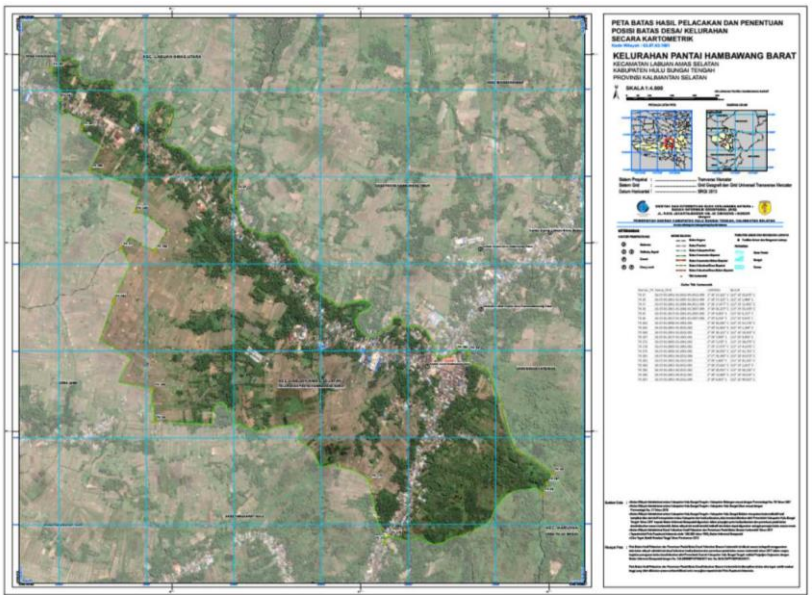

Figure 9. The final village boundary map

4. CONCLUSIONS

1. Cartometric method has been succesfully applied in Hulu Sungai Tengah Regency as an alternative model to accelerate village boundary map.
2. The ortho-rectified high resolution satellite imagery such as Pleiades and WorldView-2 are very powerfull tools to be used in mapping the village boundary, especially at the area where topographical map at scale of 1:5,000 are unavailable
3. The study was establish successfully 127 village boundary map from total of 169 villages in Hulu Sungai Tengah Regency, South Kalimantan Province.
4. The success of village boundary mapping depend highly on the quality of data sources as well as by the willingness and support from local governments, especially village, sub-district and district officials.

5. ACKNOWLEDGEMENT

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