CAN THE PEAT THICKNESS CLASSES BE ESTIMATED FROM LAND COVER TYPE APPROACH?

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Abstract. Indonesia has been known as a home of the tropical peatlands. The peatlands are mainly in Sumatera, Kalimantan and Papua Islands. Spatial information on peatland depth is needed for the planning of agricultural land extensification. The research objective was to develop a preliminary estimation model of peat thickness classes based on land cover approach and analyse its applicability using Landsat 8 image. Ground data, including land cover, location and thickness of peat, were obtained from various surveys and peatlands potential map (Geology Map and Wetlands Peat Map). The land cover types were derived from Landsat 8 image. All data were used to build an initial model for estimating peat thickness classes in Merauke Regency. A table of relationships among land cover types, peat potential areas and peat thickness classes were made using ground survey data and peatlands potential maps of that were best suited to ground survey data. Furthermore, the table was used to determine peat thickness classes using land cover information produced from Landsat 8 image. The results showed that the estimated peat thickness classes in Merauke Regency consist of two classes, i.e., very shallow peatlands and shallow peatlands. Shallow peatlands were distributed at the upper part of Merauke Regency with mainly covered by forest. In comparison with Indonesia Peatlands Map, the number of classes was the two classes. The spatial distribution of shallow peatlands was relatively similar for its precision and accuracy, but the estimated area of shallow peatlands was greater than the area of shallow peatlands from Indonesia Peatlands Map. This research answered the question that peat thickness classes could be estimated by the land cover approach qualitatively. The precise estimation of peat thickness could not be done due to the limitation of insitu data.

Keywords: *Peat thickness, Landsat 8 image, land cover, Merauke Regency, shallow peatlands*

1 INTRODUCTION

Agricultural extensification is an expansion of agricultural areas by opening new land for agriculture. One of the potential land to be developed for agricultural cultivation is wetland. The area of wetland in Indonesia reached ± 33.4 million ha (Jumakir and Endrizal 2016), while the potential area for agricultural cultivation reached ± 10.2 million hectares. Papua Province has ± 2.8 million ha of potential wetland area for agriculture use, it is second ranks in Indonesia after Sumatera ± 3.9 million ha (Alihamsyah 2004). Therefore, this area is very potential for agricultural extensification for supporting of food sovereignty programs in Indonesia.

The type of soil in wetland may be alluvial or peat. The alluvial soil is a precipitate formed from a mixture of materials such as mud, humus, and sand with different mixing ratios, while Peat is the result of weathering of organic materials such as leaves, branches, and shrubs in a state of saturated water for a very long time. A soil is called peat soil if the peat thickness is more than 50 cm, thus, peatland is wetland with peat thickness greater than 50 cm (Driessen 1978). Indonesia has the largest peatlands among tropical countries, which is about 21 million ha, spread mainly in Sumatera, Kalimantan and Papua (BB Litbang SDLP 2008). Most of the peatlands are still forest cover and are habitat for various species of fauna and rare plants. More importantly, peatlands store carbon (C) in large quantities. Peat also has a high water holding power so that it serves as a buffer hydrology surrounding areas. Peatlands conversion will disrupt all the functions of the peatlands ecosystem (Agus and Subiksa 2008).

Based on Law no. 80, 1999 on General Guidelines for Planning and Management of Peatlands Development Zone in Central Kalimantan, peatlands with thickness less than three meters can be used for forestry, agriculture, fishery, and plantation cultivation, while peatlands with thickness more than three meters are used for conservation. Although the law is specifically designed to address the problem of peatlands in Central Kalimantan, but the law generally can be applied in peatlands in other areas (Tjahjono 2006). Therefore information on peat thickness is needed to determine the policy of peatlands utilization for agricultural activities.

The utilization of remote sensing data for the identification, mapping and utilization of peatlands has been done in several studies. (Setiawan *et al.* 2016) identified 23 types of significant patterns of Enhance Vegetation Index (EVI) from MODIS imagery that were characterized by land cover type and peat depth. The EVI patterns indicated different types of ecosystems and/or different response of ecosystems to the changing environment in the Sumatera. Peat depth modelled was developed as a function topography (Rudiyanto *et al.* 2015), and also as a function topography and spatial position (Rudiyanto *et al.* 2016) for Sumatera and Kalimantan Islands. The spatial models were calibrated with the ground observations, and the models of the peat depth prediction were 0.67 to 0.92 of coefficient determination. (Jainicke *et al.* 2008) used DEM SRTM and Landsat ETM + imagery to delineate boundary of peat domes (i.e. peat accumulation that results in a form structure like a dome) in seven locations in Indonesia. (Wahyunto *et al.* 2004) estimated carbon stock using a product of peat area, depth/thickness of peat, carbon content and bulk density, after they delineated the peat distributions into land mapping units or polygons.

The uses of radar data were also conducted to identify and map the peat thickness. (Prihastomo 2016) was using ground penetrating radar (GPR) method to estimate peat thickness in Riau Siak Region, and obtained result that the estimated peatlands thickness in study area was ranged about 0.5-4.5 m. (Kripsiana 2015) utilized Light Detection and Ranging (LiDAR) to build digital terrain model (DTM), further the DTM was used for peat mapping for Kampar Riau region. At the national scale, peat thickness mapping has also been conducted based on a combination of satellite data and ground survey data.

Beginning with the question whether the peat thickness could be classified using optical remote sensing data, the research objective is to analyse and develop a preliminary estimation model of peat thickness classes based on land cover approach and analyse its applicability using Landsat 8 image. The preliminary estimation model of peat thickness classes was developed using ground survey data, peatlands map, and Landsat 8 image.

2 MATERIALS AND METHODOLOGY

The study area was located in Merauke Regency, as shown in Figure 2-1. Merauke Regency was adjacent to Mappi and Boven Digoel regencies in the north, with Arafuru Sea in the south, and Papua New Guinea in the East. The spatial data used in this research consisted Landsat 8 satellite mosaic imagery period 2015-2016 to produce land cover information of Merauke Regency, Geology Map of 1995 from Geology Research and Development Center, and Peatlands Map of 2000-2001 from Wetlands International Indonesia Wetlands (2006). Ground survey was conducted on 30 October-4 November 2016 by joint survey team consisting of Remote Sensing Applications Center (Pusfatja) team and Balai Rawa Team to get information of land cover and peat thickness. This research also utilized ground measurement data from survey team of KESDM on March 18th – May 2nd 2008, (Subarnas 2008), Geodesy Geomatics survey team in 2009-2010 (survey related to exploration geoelectric and Geology parameters in South Papua) and survey team from Papua Provincial Mining Department. The survey data from the geodesy survey team and the Papua Provincial Mining Department survey team were obtained from discussions with them.

The flowchart of this research is shown in Figure 2-2. The survey data provided information about location coordinates, land cover conditions and peat thickness in several locations of study area. Location coordinates and peat thickness were used to evaluate the more suitable maps to determine peatlands boundaries in Merauke Regency. The evaluated maps were the Geology Map and Peatlands Map of Wetlands. After determining the more suitable map, the information on the map was used to determine peat potential area (peat areas and peatlands boundaries).

The relationship between land cover on peat potential areas and peat thickness classes was analysed based on ground survey measurements, both conducted by joint survey team, as well as ground survey from other teams. Furthermore, a relationship table between land cover and peat thickness class was developed. The peat thickness classes referred to the definition of Climate Change forests and Peatlands in Indonesia (CCFPI) and several publications (Agus and Subiksa 2008; Syahruddin and Nuraini 1997).

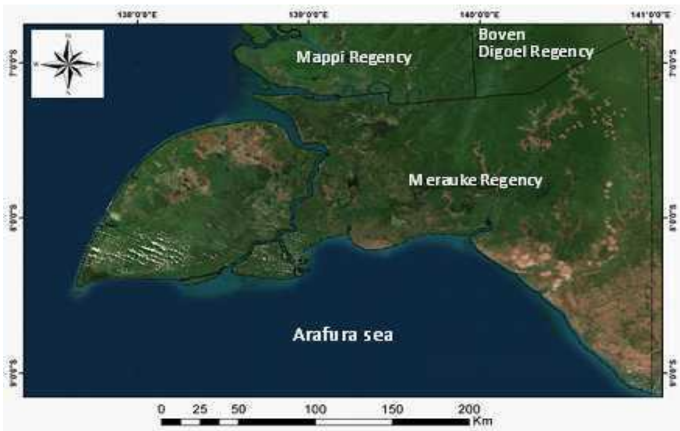

Figure 2-1: Study area in Merauke Regency

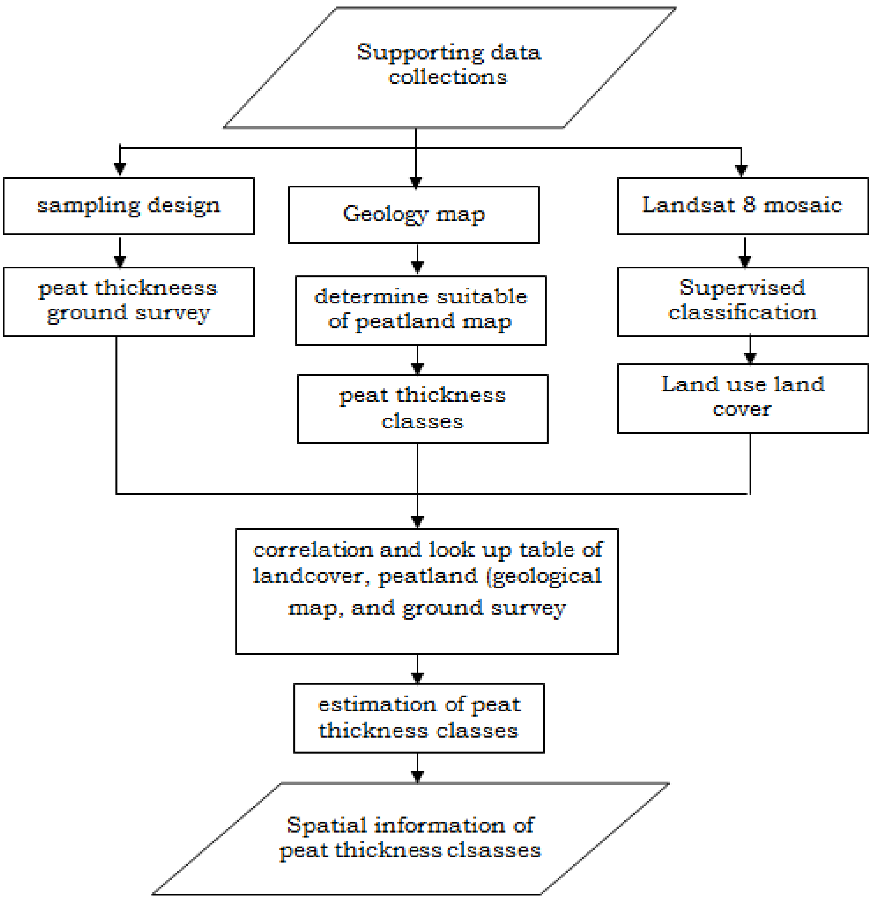

Figure 2-2: Flowchart of preliminary estimation (peat thickness classes)

The relationship table between land cover and peat thickness classes then were used to estimate peat thickness class based on land cover information of Merauke Regency. Land cover information was made using Landsat 8 2015-2016 mosaic imagery using visual interpretation and on screen digitation method. Land cover classes consisted forest, plantation, shrub, cultivated land, rice field, savannah pasture, settlement, swamp, mangrove, water body and open land. The Land cover information was overlaid with peatlands boundary from the map, so the distribution land cover on peatlands area was obtained. The next step was to predict peat thickness class on each land cover type using the relationship table between land cover and peat thickness classes, and then verify the results with ground survey data.

3 RESULTS AND DISCUSSION

The joint ground survey was conducted by Pusfatja and Balai Rawa teams to observe land cover conditions and measure peat thickness at 64 location points in the southern part of Merauke Regency, as shown in Figure 3-1. Peat thickness measurements were carried out by drilling at four representative location points. Based on the observation of the land cover condition, most of the survey location points (77%) were performed at very shallow peatlands (peat thickness less than 50 cm) with various land cover, i.e. swamp, rice field, plantation, forest and shrub. While the other survey location points were performed at a non peatlands area (23%) having land cover of open land, settlement and water body. In this survey, it was not found a location with peat thickness greater than 50 cm.

Furthermore, based on data from other survey teams obtained from literature and discussions with those survey team members (Ministry of Energy and Mineral Resources survey team, Geodesy Survey team and Papua Provincial Mining Department survey team), additional information was obtained regarding the condition of peatlands in Papua, as follows: KESDM team conducted a survey in period March-May 2008 in several locations of Merauke Regency (Anasai, Kumbe, Domande, Wapeko, Rawa Biru and Sota villages). The team did not found indication of peat deposits except in Anasai and Kumbe villages. The team found swamps deposits with Lithology of black clay covered by a layer of humus with a thickness about 10-15 cm (very shallow peatlands).

a. The Geodesy Geomatics team found that the area around the river basin was very shallow peatlands with a thickness about 0-50 cm.
b. Mining Department survey team found that the area observed was very shallow peatlands (0-50 cm) in general, but shallow peatlands (50-100 cm) was found in forest areas around Muting district and at the upper area of Merauke Regency.

The peatlands locations and peat thickness classes obtained from the ground survey were inconsistent with information released by Peat Map of Wetlands, particularly on peat thickness classes. The Wetlands map had three classes of peat thickness for Merauke Regency, they are very shallow peatlands (0-50 cm), shallow peatlands (50-100 cm) and medium peatlands (100-200 cm).

The Geology Map did not provide information on peat thickness but provided information on the type of lithology that had the potential peat. The peatlands location obtained from the ground survey in accordance with the potential of peat from the Geology map. Based on the above considerations, the peatlands boundaries were determined using Geology Map.

Figure 3-2 shows the spatial information of lithology in Merauke Regency from Geology Map. There were 5 classes of lithology, where 2 of them are potentially peat area. Those were young swamp deposits and old swamp deposits. Based on the definition in the Geology Map, young swamp deposits were very fine-grained clay deposits composed of clays, mud, silt, and fine sand containing carbonan, whereas old swamp deposits are fine clay deposits composed of mud and fine carbonan sand, and peat. Then peat potential areas were determined by classified whole study area into 3 classes (Figure 3-3), those were:

a. Non peatlands
b. Peatlands potential (young swamp deposits)
c. Peatlands potential (old swamp deposits)

Peat-containing soils were naturally present in the uppermost layer, under the peat layer there were alluvial layers in varying thickness. Based on Climate Change Forest and Peatlands in Indonesia (CCFPI) and several publications (Agus and Subiksa 2008; Syahruddin and Nuraini 1997), peat thickness was divided into 6 classes as following:

a. Non peatlands

b. Very shallow peatlands (peat thickness less than 50 cm),
c. Shallow peatlands (peat thickness between 50-100 cm),
d. Medium peatlands (peat thickness between 100-200 cm),
e. Deep peatlands (peat thickness between 200-300 cm),
f. Very deep peatlands (peat thickness greater than 300 cm.

According to the survey data from several teams in Merauke Regency, it was found that most of the land covers in Merauke Regency were on very shallow peatlands area (peat thickness 0-50 cm). Shallow peat (peat thickness between 50-100 cm) was found in forest located in the upper part of Merauke Regency (around Muting district). While non peatlands was generally found in settlement, open land and water body. Based on these facts, a table that showed relationships among land cover, peat potential area and peat thickness classes was made, as shown in Table 3-1.

Survey location points in the southern part of Merauke Regency

Peat thickness of less than 50 cm on swamp area

Figure 3-1: Survey location and an example of peatlands in Merauke Regency

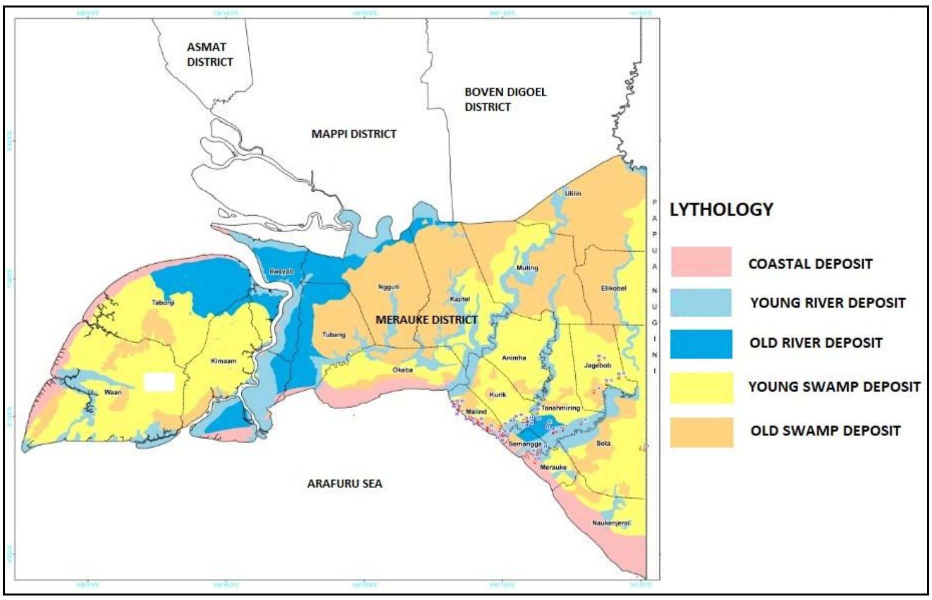

Figure 3-2: Spatial information of lithology in Merauke Regency from geology map

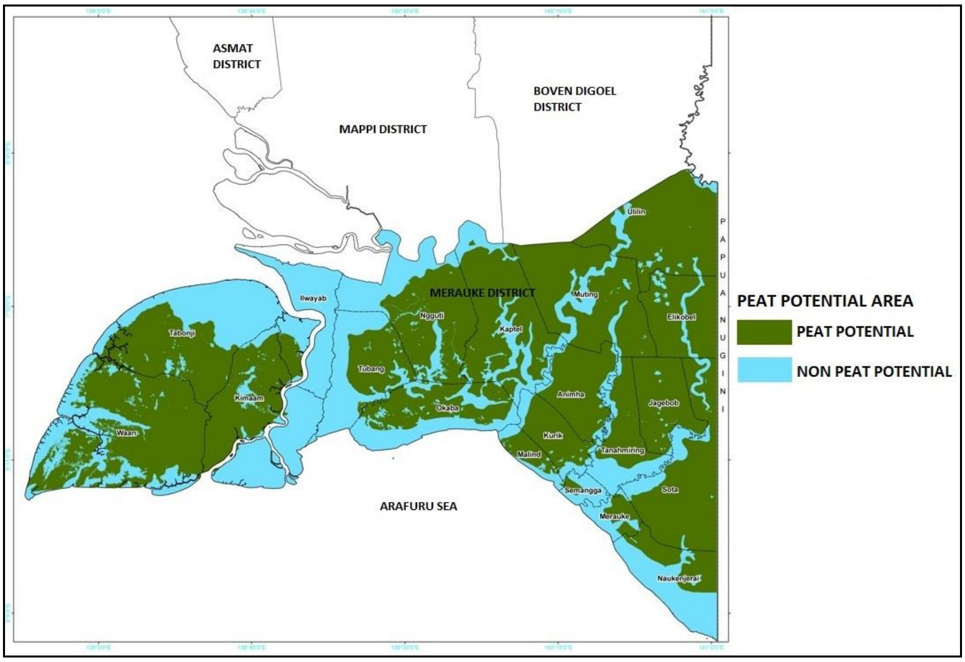

Figure 3-3: Peat potential area in Merauke Regency based on geology map

The rules of this relationship were as follow:

a. Non Peatlands class appeared when the land cover types were open land, settlement and water body, or when all types of land cover classes meet non peatlands area.
b. Shallow peatlands class appeared when forest meets peat potential area of old swamp deposits.
c. Very shallow peatlands class appeared when other land covers meet peat potential areas, young swamp deposits or old swamp deposits.

Land cover of Merauke Regency was made using six scene imageries from Landsat 8 in the period 2015-2016. Land cover information was made using visual interpretation methods and digitized on the screen. The first result of land cover information was then verified using the ground cover observation data. The accuracy of land cover information (especially for peatlands estimation) based on Landsat 8 image for the study area was more than 80 %.

Misinterpretation was often found when distinguishing several land cover types, such as shrub, cultivated land, open land, rice field and swamp. The data and knowledge about land cover condition in Merauke Regency obtained from ground survey were then used to improve the land cover classification, so that the interpretation error became minimized and the accuracy improved. Figure 3-6 showed the final result of land cover information in Merauke Regency, and land cover was divided into 11 classes.

After all data were collected, ie: spatial information on potential peat areas (Figure 3-3), spatial land cover information (Figure 3-4), and table of land cover relationships, peat potential areas and peat thickness classes (Table 3-1), then the data were overlaid and peat thickness classes were estimated using the rules in Table 3-1. The spatial information of estimated peat thickness was shown in Figure 3-5. The area of Merauke Regency was divided into three peat thickness classes, as follows:

a. Non peatlands class, it is shown in cyan color,
b. Very shallow peatlands class (peat thickness between 0-50 cm), this class (Light green) was distributed in almost all districts in Merauke Regency,
c. Shallow peatlands class (peat thickness between 50-100 cm), this class was spread at upper part of Merauke regency, especially in Muting, Kimaam, Eligobel, Ulilin, Ngguti and Kaptel districts.

Table 3-1: Correlation and look up table of land cover, peat potential area and peat thickness classes

No	Land cover	Peat potential area based on Geology Map	Peat thickness classes
1.	Forest	Non peatlands area	Non peatlands
		Young swamp deposits	Very shallow peatlands
		Old swamp deposits	Shallow peatlands
2.	Plantations	Non peatlands area	Non peatlands
		Young swamp deposits	Very shallow peatlands
		Old swamp deposits	Very shallow peatlands
3.	Shrub	Non peatlands area	Non peatlands
		Young swamp deposits	Very shallow peatlands
		Old swamp deposits	Very shallow peatlands
4.	Cultivated land	Non peatlands area	Non peatlands
		Young swamp deposits	Very shallow peatlands
		Old swamp deposits	Very shallow peatlands
5.	Open land	Non peatlands area	Non peatlands
		Young swamp deposits	Non peatlands
		Old swamp deposits	Non peatlands
6.	Settlement	Non peatlands area	Non peatlands
		Young swamp deposits	Non peatlands
		Old swamp deposits	Non peatlands
7.	Swamp	Non peatlands area	Non peatlands
		Young swamp deposits	Very shallow peatlands
		Old swamp deposits	Very shallow peatlands
8.	Mangrove	Non peatlands area	Non peatlands
		Young swamp deposits	Very shallow peatlands

No	Land cover	Peat potential area based on Geology Map	Peat thickness classes
		Old swamp deposits	Very shallow peatlands
9.	Water body	Non peatlands area	Non peatlands
		Young swamp deposits	Non peatlands
		Old swamp deposits	Non peatlands
10.	Rice field	Non peatlands area	Non peatlands
		Young swamp deposits	Very shallow peatlands
		Old swamp deposits	Very shallow peatlands
11.	Savanna pasture	Non peatlands area	Non peatlands
		Young swamp deposits	Very shallow peatlands
		Old swamp deposits	Very shallow peatlands

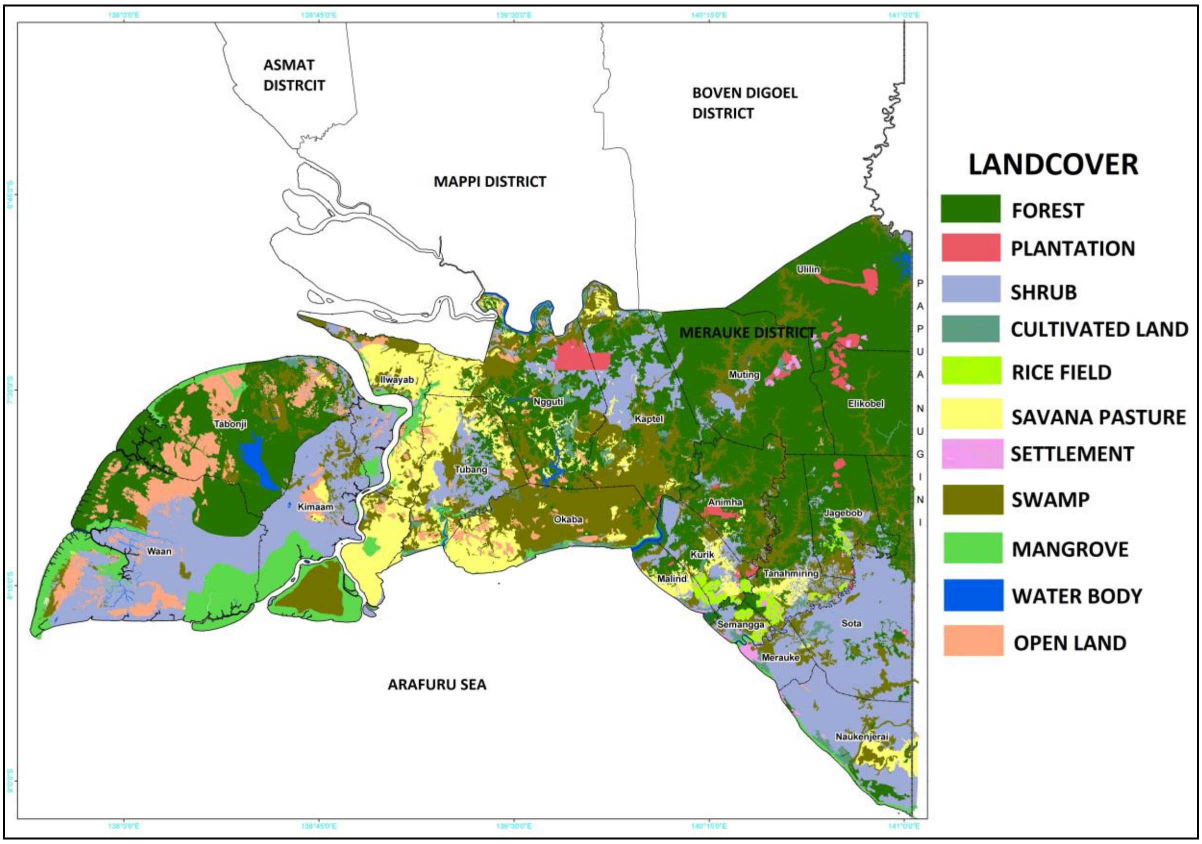

Figure 3-4: Spatial information of land cover in Merauke Regency in period 2015-2016

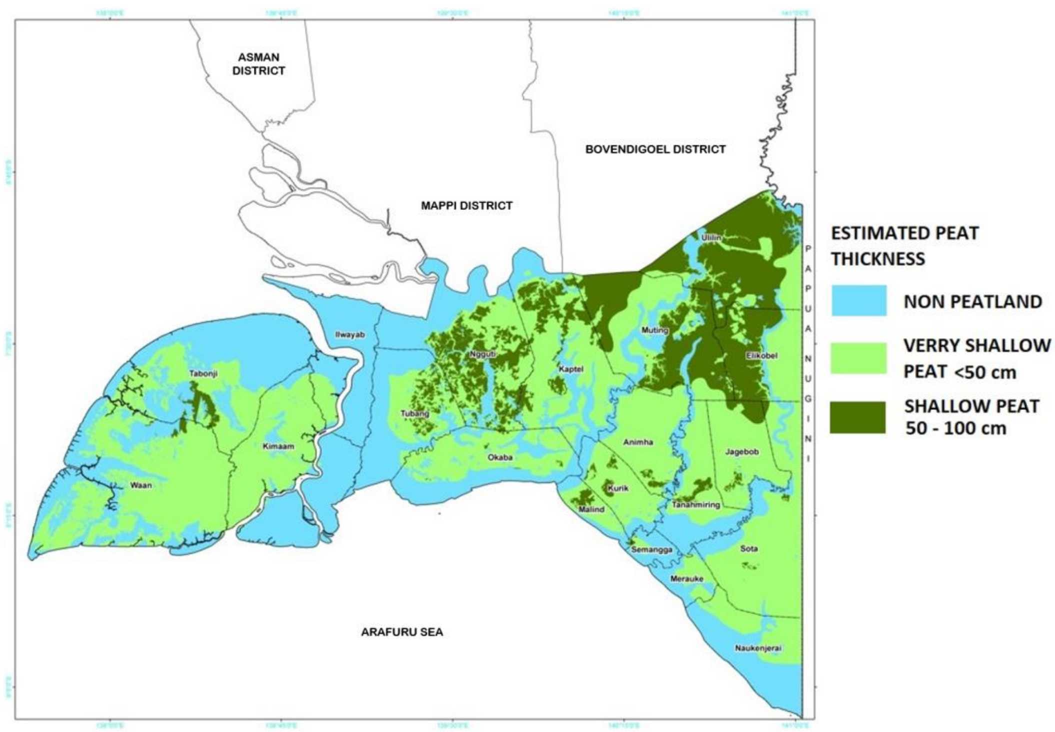

Figure 3-5: Spatial information of estimated peat thickness classes in Merauke Regency

Estimated peat thickness classes in Merauke Regency obtained from this research was evaluated by comparing the result with Indonesia Peatlands Map with scale 1: 250.000 issued by the Ministry of Agriculture (Kementan 2011) for the December 2011 edition. This map were made using ground survey data and land mapping with various scales of 1: 250.000, 1: 100.000 and 1: 50.000. Indonesia peatlands map divided peat thickness classes in Merauke Regency (Figure 3-6) into 2 classes: D0 class (peat thickness less than 50 cm), and D1 class (peat thickness between 50-100 cm). Even the map stated D0 class as one of peat thickness classes, but D0 class was not spatially displayed in the map, because it is though due to peat thickness less than 50 cm can be classified as non-peatlands (Driessen 1978).

The comparison of the estimated peat thickness classes produced in this activity with Indonesia Peatlands Map showed that the number of peat thickness classes in Merauke Regency was almost the same, where there were two peat thickness classes, i.e. very shallow peatlands (peat thickness less than 50 cm) and shallow peatlands (peat thickness between 50-100 cm). According to the area and location of peatlands in Merauke Regency, the comparison was only be done in shallow peatlands. The area of shallow peatlands in Indonesian Peatlands Map was smaller than the estimated shallow peatlands, and the location of the shallow peatlands in the Indonesian Peatlands Map was relatively similar or adjacent to the location of estimated shallow peatlands obtained from this activity. Further analysis showed that the shallow peatlands obtained from Indonesia Peatlands Map was located in forest and swamp area. According to geostatistical test, the confidence level 3σ or more than 90 %, most of shallow peatlands was located in forest and swamp area.

In fact, information of peat thickness had been issued in some maps, such as Indonesia Peatlands Map from Ministry of Agriculture or Map of Peatlands

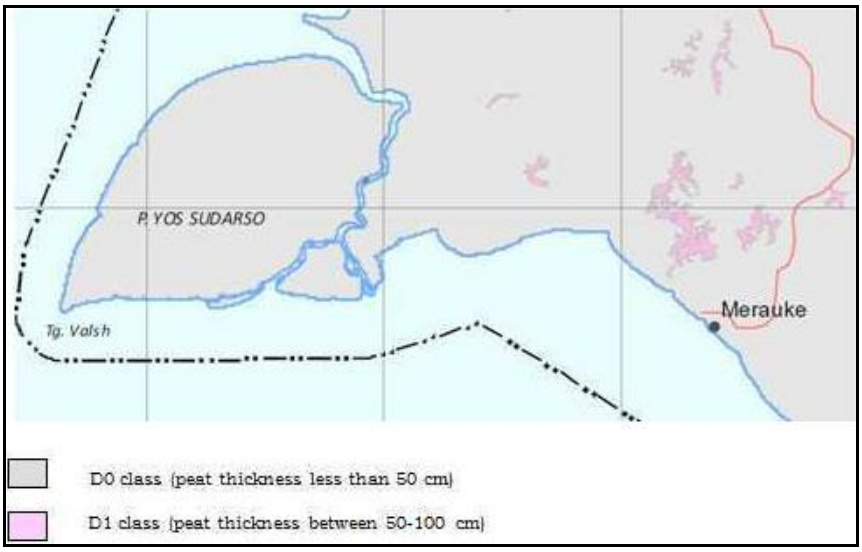

Figure 3-6: Peat thickness classes in Merauke Regency from Indonesia peatlands map

Distribution Area and Carbon Content in Kalimantan from Wetlands International. But their results are quite different, so it makes difficult for user to determine which information is correct and can be used as a reference. Therefore, the ground survey data becomes a very important reference data to evaluate the accuracy of the produced information. According to Adjustment (Geodesy-Statistic), Remote Sensing data is only focus in precision, not focus in accuracy. Accuracy will be have high true value and least bias value if it compares the ground data using least square adjustment methods. The advantages of this model are having higher level of precision, effective in cost mapping, efficient and time use especially in preliminary surveys. The weakness of the resulted model is the level of object detail and it has not been tested into other areas.

This model is only used for preliminary survey of geology, mining, and others engineering.

Ground surveys are still required for ground checking as these models have not yet produced higher accuracy. Improving the accuracy model needs to change the algorithm by least square adjustment approach. Least square adjustment is one of the geodesy statistical (geostatistical) method to get high true value, least bias value, and minimum error. It also required multi-sensor data for more precise mapping.

4 CONCLUSION

The results have shown that preliminary estimation model of peat thickness classes could be developed using land cover condition approach on Landsat 8 image. The preliminary estimation of peat thickness classes was verified against the Indonesian peat map. The peat potential area was determined using Geology Map because it was relatively similar with ground survey data. The preliminary estimation of peat thickness model was conducted using a table of relationships among land cover, peat potential areas and peat thickness classes constructed using ground survey data and Geology Map. Very shallow peatlands class (thickness less than 50 cm) was spread in almost all districts in Merauke Regency, whereas shallow peat thickness class (thickness between 50 - 100 cm) was found at the upper part of Merauke Regency.

The verified result shows that the shallow peatlands area of the estimated shallow peatlands was relatively similar with the Indonesia peatlands Map, and the location of shallow peatlands of Indonesian Peatlands Map was relatively similar or adjacent to the location of estimated shallow peatlands.

The advantages of this model is to have a higher level of precision, effective in cost mapping, efficient and time use especially in preliminary surveys. The weakness of the resulted model is the level of object detail (LoD) not fully satisfying and it has not been tested and proven for other areas. To improve the model accuracy, the algorithm needs to be changed by least square adjustment approach. It also required multi-sensor data for more precise mapping.

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REFERENCES

Agus F., Subiksa IGM, (2008), Lahan Gambut: Potensi untuk Pertanian dan Aspek Lingkungan. Balai Penelitian Tanah dan World Agroforestry Centre (ICRAF) Bogor (in Indonesian).

Alihamsyah T., (2004), Potensi dan Pendayagunaan Lahan Rawa untuk Peningkatan Produksi Padi, Ekonomi Padi dan Beras Indonesia. Badan Litbang Pertanian, Jakarta (in Indonesian).

Driessen PM, (1978), Peat Soils. in: IRRI. Soil and Rice. IRRI, Los Banos, Philippines, 763-779.

Jaenicke J., Rieley JO, Mott C., *et al.*, (2008), Determination of the Amount of Carbon Stored in Indonesian Peatlands. Geoderma 147:151–158. doi:10.1016/j.geoderma.2008.08.008.

Jumakir, Endrizal, (2017), Optimizing Land with Surjan System Through Crop Diversification in Lowland Swamp Jambi Province. Jurnal Penelitian Pertanian Terapan Vol. 17 (1):26-32 (in Indonesian).

Kripsiana AA, (2015), Pembuatan Peta Kedalaman Lahan Gambut Berbasis MTD Hasil Pemetaan Lidar. Undergraduated Thesis, Universitas Gadjah Mada Yogyakarta (in Indonesian).

Prihastomo L., (2016), Ketebalan Gambut Menggunakan Metode Ground Penetrating Radar (GPR) di Daerah Siak Riau. Undergraduated Thesis, Universitas Pembangunan Nasional "Veteran" Yogyakarta (in Indonesian).

Rudiyanto, Minasny B., Setiawan BI, *et al.*, (2016), Digital Mapping for Cost-Effective and Accurate Prediction of the Depth and Carbon Stocks in Indonesian Peatlands. Geoderma 272 (2016) 20–31.

Rudiyanto, Setiawana BI, Ariefa C., *et al.*, (2015), Estimating Distribution of Carbon Stock in Tropical Peatland using a Combination of an Empirical Peat Depth Model and GIS. Procedia Environmental Sciences 24 (2015) 152 – 157.

Setiawan Y., Pawitan H., Prasetyo LB, *et al.*, (2016), Characterizing Spatial Distribution and Environments of Sumatran Peat Swamp Area using 250 m Multi-Temporal MODIS Data. Procedia Environmental Sciences 33 (2016) 117 – 127.

Subarnas A., (2008), Inventarisasi Endapan Gambut Daerah Kabupaten Merauke, Provinsi Papua, Http://Psdg.Bgl.Esdm. Go. Id/ (in Indonesian).

Syahruddin AK, Nuraini, (1997), Identifikasi Gambut di Lapangan, Lokakarya Fungsional Non Peneliti 1997 (in Indonesian).

Tjahjono EJA, (2006), Kajian Potensi Endapan Gambut Indonesia Berdasarkan Aspek Lingkungan. Proceeding Pemaparan Hasil-Hasil Kegiatan Lapangan Dan Non Lapangan Tahun 2006, Pusat Sumber Daya Geologi (in Indonesian).

Wahyunto S., Ritung, Subagjo H., (2004), Maps of Area of Peatland Distribution and Carbon Content in Sumatera, 1990–2002. Bogor, Indonesia: Wetlands International - Indonesia Programme & Wildlife Habitat Canada (WHC).

Wetlands, (2006), Peta-Peta Sebaran Lahan Gambut, Luas dan Kandungan Karbon di Papua. Wetlands International-Indonesia Programme (in Indonesian).