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Estimation of Peatland Distribution Using Ratio Dual-pol from Sentinel-1A

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Abstract. In Indonesia, forests fires particularly in tropical peatland have are a major problem unresolved. These conditions need a strong peatland management to control and reduce forest fires. Monitoring peatland conditions are crucial for the actions. Additionally, Synthetic Aperture Radar (SAR) images have wide applications in remote sensing and mapping. It utilized area when meteorological conditions are not suitable for acquirement of optical data. In this research, we used a dual-pol (VV and VH) Sentinel-1A and estimated soil moisture of peat in Siak Regency, Riau Province, Indonesia using a modified Dubois Inversion. At the site, soil moisture at the four selected segments (namely, A1, A2, D1 and J1) are also measured in May 2017. Results show that the peatland areas have a ratio of polarimetric features (VH/VV) of 1.5 to 1.6.

Keywords: Peatland, Sentinel-1A, SAR, Dual-Pol, Ratio, Backscattering

1. Introduction

Indonesia is a country with the largest tropical peatland area in the world, covering an area of 21 million hectares spread throughout Indonesia [1]. Distribution of peatland increasingly required by many. These were caused by the increased understanding of the peatland. However, constraints in the mapping of peatland are the limited field survey data because of low accessibility to the peat, so that the role of spatial data becomes very important. Wetlands by nature are the transitional area between terrestrial and aquatic systems. Knowing the potential distribution of global wetlands could facilitate our understanding wetland development, wetland changes, and decision-making for wetland restoration and protection [2]

In Indonesia, peatland are managed for cultivation areas, namely for food crops, plantation crops, and industrial plantation forests. Agricultural land clearing is carried out by drying peatlands, during the drought period, coupled with the El Nino phenomenon, causes the table of peat water to be very low (often more than 2 meters below the surface) and thus accelerates the oxidation of dry peat. At the same time the peat is very vulnerable to burning (WWF Indonesia, 1999). It causes peatland fires always occurs every year, not just regulatory and socio-economic issues, but the availability of peat maps that have not been updated has made stakeholders difficult in making policies and decisions. Therefore, the peat map is very important for stakeholders as a reference in policy making. In addition to inventorying natural resources, monitoring peatland is needed as an effort to mitigate peat fires that often occur in Indonesia.



Because of high cloud cover in Indonesia, using active remote sensing (SAR) in mapping and land use is very important compared to the use of optical remote sensing data [3] possible with radar satellite remote sensing [4]. Synthetic Aperture Radar (SAR) is an advanced technology that can provide accurate spatial data, fast and efficient to knowing the potential distribution of peatlands.

However, mapping of peat is very difficult, peat is a wetland so the SAR becomes ineffective. Several authors have reported strong relationships between SAR backscatter and measured soil moisture. [5]. Synthetic Aperture Radar (SAR) has been shown to be sensitive to surface soil moisture, and is therefore a promising alternative to field data campaigns. However, the presence of spatially variable vegetation and surface roughness also affect SAR backscatter [5].

This study uses SAR Sentinel-1A data. Sentinel-1A is a polar SAR orbit satellite developed by European Space Agency (ESA) to support Global Monitoring for Environment and Security program. This satellite has a C-Band SAR sensor that produces single polarization data (HH and VV) and dual polarization data (HH + HV; VV + VH). One of the missions of the satellite is to provide high-quality image products to support monitoring of agriculture and forests. Our study presents a method to peatland classifies using backscattering from the dual polarization Sentinel-1A (VV + VH).

2. Material and Methods

2.1. Study Area

The study sites (1.275 °N, 100.906 °E – 0.347 °N, 102.183 °E) located at Siak Regency, Riau Province, Indonesia (Figure. 1). The study area has a total area of 8275 km and is in a tropical rainy climate zone. The annual temperature ranges between 25 °C and 32°C, with the mean annual temperature is 28 °C [6]. Siak has a large peatland of 6,436,649 ha with a balanced area between shallow depths of 70 cm (50-100 cm) to very deep (> 300 cm) (BBSDLP in 2011). In addition, in situ measurements of soil moisture were carried out at 4 survey locations in SIAK (500 x 500 m). Satellite imagery were used in the study is Sentinel-1A with dual polarimetry (VH + VV) on May 2017.

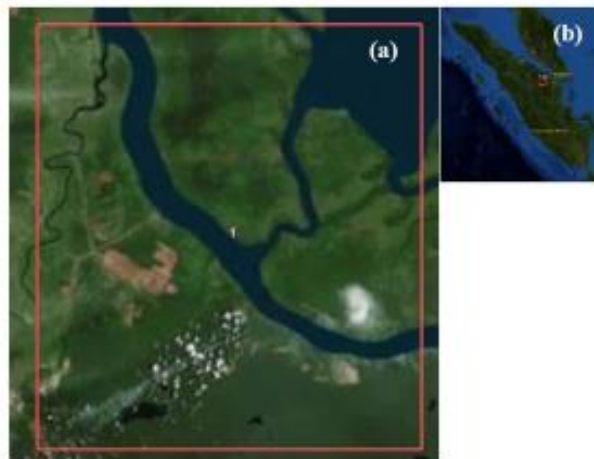


Figure 1. Study site (a) in Sumatra Island, Indonesia (b).

2.2. Field data

Field measurements of soil moisture have been collected from bare plots selected over the study areas. In situ measurements of soil moisture collected by soil moisture meter on four observation segments (Table 1). The in-situ data were collected during the field campaigns from 4 May to 16 May 2017. The volumetric soil water content (SWC) of the top 5-cm layer and the top 10-cm layer were measured with Soil Moisture Meter Model: PMS-714. To avoid diurnal variation of SWC as the effect of soil temperatures and respirations, we set the time of the measurements in the morning between 07h and 10h local time. The

numbers of chosen measurement points were equal to 250. The geographic coordinates were recorded using a Global Positioning GPS receiver with the accuracy of 5 m. [6]. Table 1 shows that segment of A1 and D1 are not peatlands.

Table 1. List of site locations and vegetation types

Site Name	Longitude (deg-min-s)	Latitude (deg-min-s)	Peat Condition (Peat depth*)	Dominant vegetation covers
A1	102°07'46.9"E	1°08'40.9"N	Disturbed and no/less peat	Oil palm
A2	102°10'07"E	1°09'56.2"N	Disturbed and thick peat (3.46 m)	Shrubs/fern plants, oil palm, and agriculture (Pineapples)
B1	102°04' 12.72" E	1°05' 15" N	Disturbed and thick peat	Oil palm, Shrubs
C2	102° 0' 45" E	1°01'10.2" N	Disturbed and thick peat	Oil palm
D1	102°06'58"E	1°09'14.0"N	Disturbed and no/less peat	Paddy field
D2	102°08' 24.72" E	0°58'48.36" N	Disturbed and thick peat	Oil palm
E1	102°11' 35.52" E	0° 56' 3.84" N	Disturbed and thick peat	Oil palm, Shrubs
F2	102°04'52.32" E	0°52'30.72" N	Undisturbed and thick peat	Open space
I1	102° 2' 39.12" E	0°48'57.96" N	Undisturbed and thick peat	City Park
J1	102°15'55.3"E	0°40'00.5"N	Undisturbed and thick peat (> 7.6 m)	Peat swamp forest

* Averaged peat depth that measured by coring

2.3. SAR Data Processing Method

2.3.1. Ratio backscattering.

SAR can measure the backscattering coefficient of a surface. The process of processing SAR data including the slope and ortho-rectification correction process helps to eliminate roughness in SAR data up to a certain time limit. This pre-processing data results in a digital number (DN) derived from the amplitude signal extracted from the SAR image, which is then converted to the backscatter coefficient (σ^0 , unit: dB). in this study, backscatter values were obtained through several steps of the pre-processing process using SNAP software.

The Oh model uses the ratios of the measured backscatter coefficients $p = \sigma_{HH}^0 / \sigma_{VV}^0$ and $p = \sigma_{HV}^0 / \sigma_{VH}^0$. Cross-polarized backscatter coefficient σ_{HV}^0 to estimate volumetric soil moisture and surface roughness. [7]. In 2008, research results by Rao mention that the depolarization ratio (VH to VV polarization) was found to be very sensitive to soil surface roughness. Therefore, the value of surface roughness can determine soil moisture, and soil moisture can determine peat.

2.3.2. Dielectric Constant

In this study, backscatter values were obtained through several steps of the pre-processing process. Then to determine the ratio backscattering that will be used in peat classification, the calculation of soil moisture is needed as a result of processing validation and the results of field data retrieval, the backscatter value of the HH and VV polarization images is used to estimate the value of the dielectric constant (ϵ') using the formula the Semi-Empirical Dubois Model [8] as follows:

$$\varepsilon' = \frac{\left(\frac{\log(\sigma_{HH}^0)^{0.7857}}{\sigma_{VV}^0} \right) 10^{-0.19} \cos^{1.82} \theta \sin^{0.93} \theta \lambda^{0.15}}{-0.042 \tan \theta} \quad (1)$$

where ε' is the soil dielectric constant and θ is the angle formed / incident ($^\circ$). Dubois et al. proposed a semi-empirical model for simulating the backscattering coefficients in HH and VV polarizations on bare soils is expressed as:

$$\sigma_{HH}^0 = 10^{2.75} \frac{\cos \theta^{1.5}}{\sin \theta^5} 10^{0.028 \varepsilon_r \tan \theta} (kh \sin \theta)^{1.4} \lambda^{0.7} \quad (2)$$

$$\sigma_{VV}^0 = 10^{2.5} \frac{\cos \theta^3}{\sin \theta^3} 10^{0.046 \varepsilon_r \tan \theta} (kh \sin \theta)^{1.1} \lambda^{0.7} \quad (3)$$

where θ is the angle of arrival (around 23.5° (the middle value of the angle value is 20° to an angle of 27°)), $k=2\pi/\lambda$ is the number of free waves, λ is free wavelength (5.6 cm) and h is Root Mean Square (RMS) roughness of the surface height with is a real dielectric constant [9].

Satellite imagery were used in the study is Sentinel-1A dual polarimetry (VH and VV) on Mei 2017. The inversion of the Dubois model was done as follows:

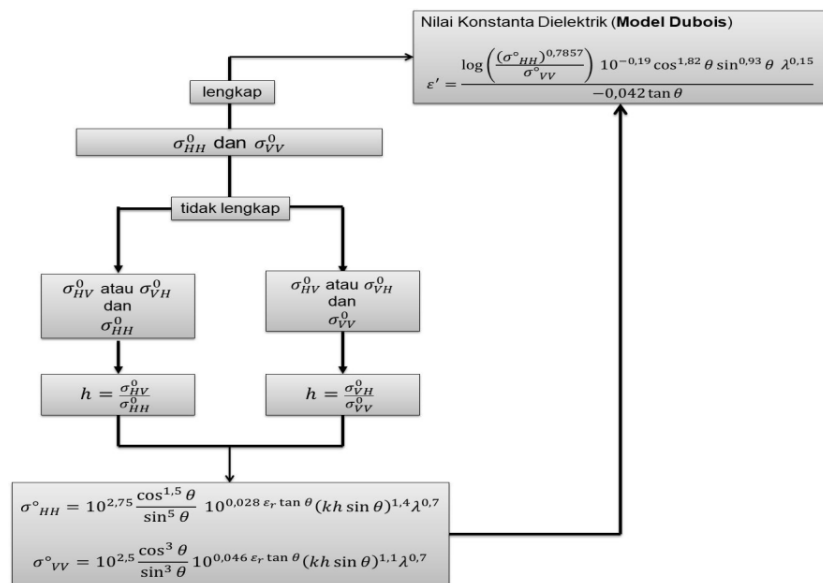


Figure 2. Dubois Model Modification Workflow In Calculating Dielectric Constant Value and Soil Moisture

3. Results and Discuss

SAR backscatter at VH polarization (σ_{VH}^0) and VV polarization (σ_{VV}^0) after the selection processes are shown in Figure 3a. and Figure 3b. The field data are 10 segments with area plot of 250.000 m². Based on this figure, median value of backscatter VH polarization (σ_{VH}^0) of the 10 segments ranges from -20 dB to -10 dB, while the median value of backscatter VV polarization (σ_{VV}^0) ranges between -15 dB and -5 dB.

D1 has a lowest median value. This segment is a segment of paddy field during the vegetative phase 1. This phase is still flooded by water so that the value of backscatter is very small. Segments of A2, B1, F2, I1, and J1 have the same median value of backscatter VH polarization (σ_{VH}^0) with an average value ranges between -13.17 dB and -12.95 dB. This information will be used in classification.

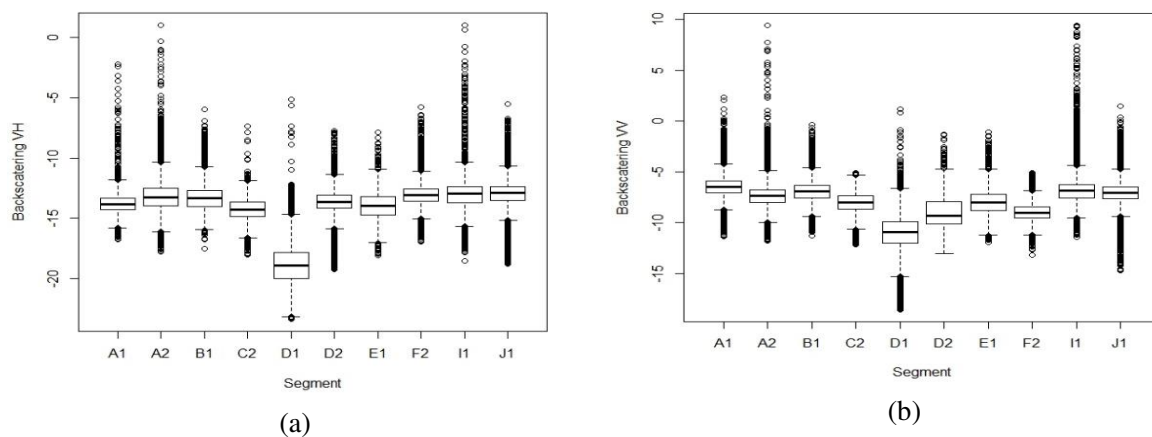


Figure 3. Backscattering value of Sentinel1A (VH/VV) On Mei 2017, Siak Regency

SAR provides information in the form of backscattering in describing a surface, so that in this study, we look for the value of the SAR backscattering ratio that represents peatland. This study found that ratio SAR backscatter ($\sigma_{VH}^0/\sigma_{VV}^0$) of the 8 segments (A2, B1, C2, D2, E1, F2, I2, and J1) are the peatlands with the ratio interval of 1,5 - 2,5 (Figure 3).

Based on the results of many study, the dielectric constant of Air (20 °C) is 80, we can approach this value as peat. Figure 4b shown that segment of D and F2 are the peats. Misclassification of the 6 segment (segment A2, B1, C2, E1, I2, and J1) occurred due to the effect of canopy. Sentinel 1A is a C-Band radar that has a short wavelength. It cannot touch the surface of the ground, and hit by the canopy (oil palm), therefore, the resulting of backscattering value represent the value of the canopy. Consequently, in this study we choose segment D2 and F2 as peat profile and ignore values from other segments.

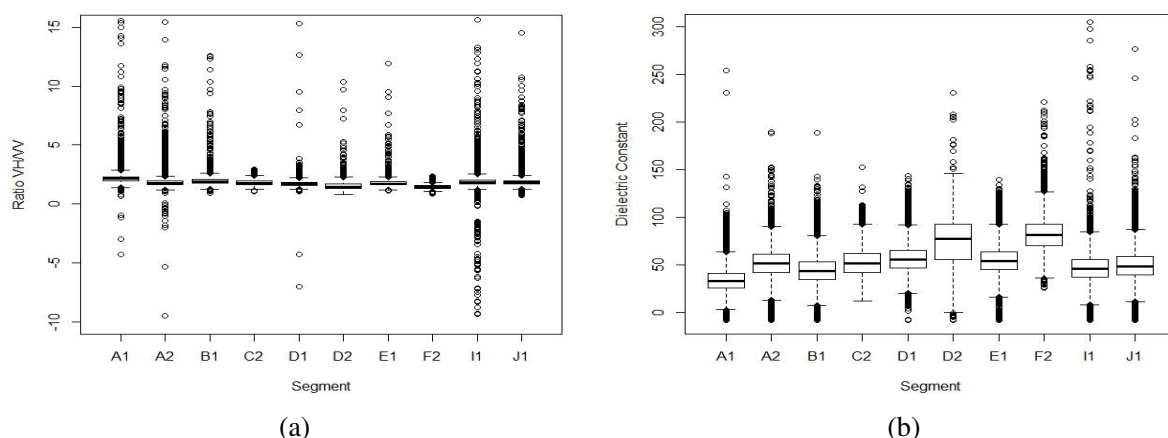


Figure 4. Backscattering ratio (a) and dielectric constant (b) of Sentinel-1A (VH/VV) on May 2017, Siak Regency

The results show that backscattering ratio ($\sigma_{VH}^0/\sigma_{VV}^0$) with the interval of 1.4 - 1.8 represented as the peatland (Figure 5). However, in the classification of peatland, some additional parameters are needed, as well as the addition of field survey data with soil samples.

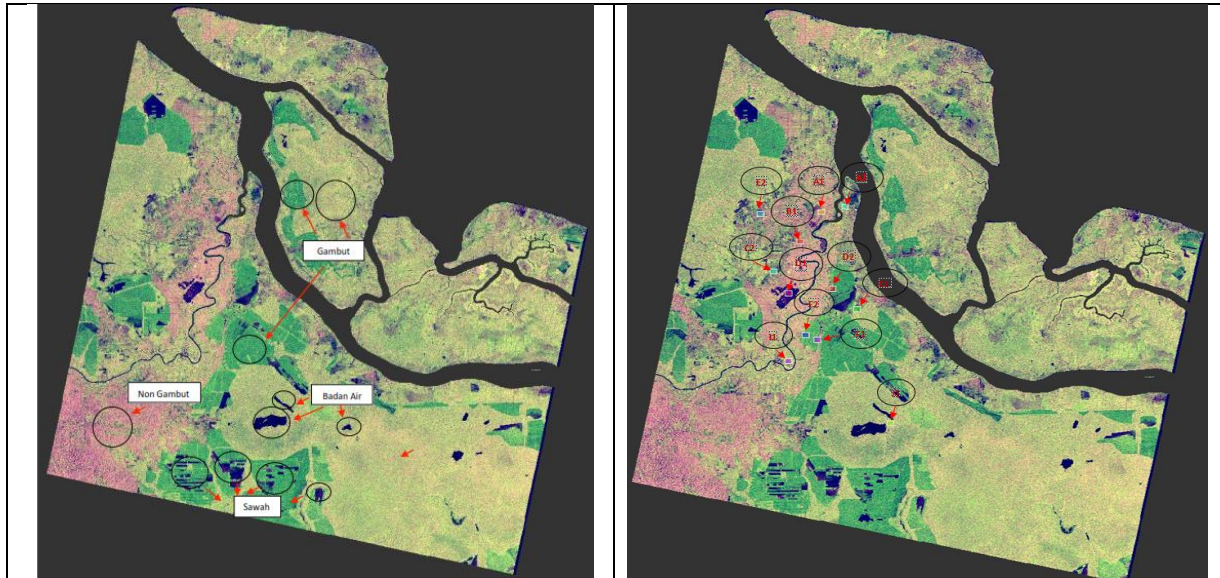


Figure 5. Peat classification in Siak uses the Sentinel-1A backscattering ratio

The purpose of this article was to classify peatlands using the backscattering ratio of sentinel-1A. This paper does not attempt to predict the absolute peatland by backscatter ratio measurement. However, the ratios of VH/VV backscatter match very well with the results for current peatland map by BBDSLP.

4. Conclusions

A technique for fitting ratio backscatter by polarimetric SAR for peatland classification has been presented. This approach based on the physics of radar scattering, not a mathematical construct. Note, because each peatland has different characteristics, then the result of this study is applied at Siak Regency only, but the methods can be applied for the other peatland. For the better result, comparisons to the soil moisture data are needed. Moreover, C-band is not well used in classifying canopied peatland.

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