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Tropical Peatland Identification using L-Band Full Polarimetric Synthetic Aperture Radar (SAR) Imagery (Study Case: Siak Regency, Riau Province)

Desti Ayunda, Ketut Wikantika*, Dandy A. Novresiandi, Agung B. Harto, Riantini Virtriana, Tombayu A. Hidayat

Center of Remote Sensing, Institut Teknologi Bandung, Bandung, Indonesia

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ABSTRACT

From revious research reported that tropical peatland is one of terrestrial carbon storage in Earth, and has contribution to climate change. Synthetic Aperture Radar (SAR) is one of remote sensing technology which is more efficient than optical remote sensing. Its ability to penetrate cloud makes it useful to monitor tropical environment. This research is conducted in a tropical peatland in Siak Regency, Riau Province. This research was conducted to identify tropical peatland in Siak Regency using polarimetric decomposition, unsupervised classification ISODATA, and Radar Vegetation Index (RVI) from SAR data that had been geometrically and radiometrically corrected. Polarimetric decomposition Freeman-Durden was performed to analyze radar backscattering mechanism in tropical peatland, which shows that volume and surface scattering was dominant because of the presence of vegetation and open area. Unsupervised classification ISODATA was then performed to extract "shrub class". By assessing its accuracy, the class that represents shrub class in reference map was selected as the selected "shrub class". RVI then was calculated using a certain formula. Spatial analysis was then conducted to acquire certain information that average value of RVI in tropical peatland tend to be higher than in non-tropical peatland. By integrating selected "shrub class" and RVI, peat classes were extracted. The best peat class was selected by comparing with peatland referenced map which is acquired from the Indonesian Agency for Agricultural Resources and Development (IAARD) using error matrix. In this research, the best peat class yielded 73.5 percent of Producer's Accuracy (PA), 81.6 percent of User's Accuracy (UA), 66.1 percent of Overall Accuracy (OA), and 0.1079 of Kappa coefficient (Ks).

1. Introduction

Page *et al.* (2002) reported that tropical peatland is one of terrestrial carbon storage in Earth, and has contribution to climate change. Total area of tropical peatland is 11 percent of the total area of global peatland, but can store up to 19 percent of total global carbon (Page *et al.* 2011). Tropical peatlands are known to be globally significant deposits of terrestrial organic carbon with estimates ranging from 50 (Yu *et al.* 2010) to 105 GtC (Page *et al.* 2011 and Dargie *et al.* 2017) equivalent to about 15% of carbon stored in peat globally.

In addition to carbon sequestration Indonesian peat swamp forests supply many ecological benefits to large coastal populations living in and around peatland landscapes. Peat swamp forests have been historical sources of timber and non-timber forest products including food, fiber, latex, medicine, and materials for household goods. Peat forests are also high in biodiversity and are critical habitat for many rare and endangered species including Sumatran tigers, orangutans, gibbons, and leopards (Cheyne *et al.* 2011 and Nowak 2012). Despite these values, Indonesian peat swamp forests are being deforested, drained, and converted at unprecedented rates (Langner *et al.* 2007 and Margono *et al.* 2014).

Tropical peatland must be managed sustainably through monitoring act. Therefore, tropical peatland data and information are needed in order to manage the development of the land, to use the land according to its capacity and potential, while not putting its hidrological function aside.

* Corresponding Author
E-mail Address: wikantika.ketut@gmail.com

Synthetic Aperture Radar (SAR) is one of remote sensing technology which is more efficient than optical remote sensing. Its ability to penetrate cloud makes it useful to monitor tropical environment (Watanabe *et al.* 2011). Polarimetric SAR imagery can be classified both with supervised and unsupervised methods (Nurtyawan *et al.* 2018). SAR technology also can be used in day and night, which is beneficial. This research is conducted using L band SAR data (wavelength ~23 centimeters) which is suitable to monitor forest.

2. Materials and Methods

2.1. Study Area

This research is conducted in a tropical peatland in Siak Regency, Riau Province, which lies from (0.899 N, 101.955 E) to (0.943 N, 102.162 E) and (0.279 N, 102.084 E) to (0.323 N, 102.292 E). Total area of tropical peatland in Siak Regency is 504,000 hectares, which is about 12.5 percent of total area of peatland di Riau Province (Ritung *et al.* 2012).

2.2. Data

Primary data that is used in this research is ALOS PALSAR Full Polarimetric imagery, which is acquired by 16 May 2010 in ascending orbit. Off-nadir angle of the imagery is 23.1°. The data has 4 polarization mode, which are HH (Horizontal-Horizontal), HV (Horizontal-Vertical), VH (Vertical-Horizontal), and VV (Vertical-Vertical).

Referenced data that is used in this research are peatland referenced map which is acquired from the Indonesian Agency for Agricultural Resources and Development (IAARD), Ministry of Agricultural Republic of Indonesia, and land use/cover referenced map that is derived from Landsat ETM+ and is acquired by 1 May 2010. The peatland referenced map is a vector data in geodetic reference system. The land use/cover has spatial resolution 30 metres (multispectral) and 15 metres (panchromatic).

2.3. Tropical Peatland Identification Method

Several studies had been carried out to monitor tropical peatland. One of the studies is conducted by Watanabe *et al.* (2011) and had reported that the presence of vegetation layer must be taken into account to explain radar backscattering of tropical peatland, even if using high frequency signal (L-band). From perspective of SAR L-band, radar depolarization mostly happen in vegetation layer. These may be explained by the presence of cross polarization magnification and/or volume scattering.

Tropical peatland was identified by integrating scattering mechanisms and Radar Vegetation Index (RVI) values. Radar scattering mechanisms in tropical peatland was described by analyzing polarimetric decomposition of L-band SAR data. Polarimetric decomposition that was used in this research is Freeman-Durden technique, which generate 3 polarimetric parameters (surface scattering, double-bounce scattering, and volume scattering).

Polarimetric parameters were then classified into 10 classes using ISODATA technique. The classes that represent shrub class in land use/cover reference map were then combined. Through an accuracy assessment using error matrix, the best combined class was selected. Accuracy assessment was conducted in 1,292 sample points that was distributed per 250 meter. Radar Vegetation Index (RVI) was applied for paddy field, calculated by following equation (Yamada 2015).

$$RVI = \frac{8\,\sigma^{\circ}_{HV}}{\sigma^{\circ}_{HH} + \sigma^{\circ}_{vv} + 2\,\sigma^{\circ}_{HV}}$$

σ°_{HV} is cross-polarization of cross section, meanwhile σ°_{HH}, and σ°_{VV} are co-polarization of cross section, which is represented by power units. Generally, RVI is ranged between 0 and 1. The greater RVI is, the greater biomass' amount is.

RVI was then overlaid to peat reference map, and it shows that average value of RVI in tropical peatland was higher than average value of RVI in non-peatland. Therefore, RVI was classified into 3 classes based on its standard deviation (avg std), which are narrow interval class (avg ± 0.5 std dev), medium interval class (avg ± std dev), and broad interval class (avg ± 0.5 2 std dev). Those classes then was integrated with selected "shrub class".

Integration result was then extracted into peat classes. The best peat class was selected through an accuracy assessment using error matrix in 1,292 sample points. Integration that yielded the most significant accuracy parameters was selected as the best peat class.

3. Results

3.1. Polarimetric Decomposition Degree

Polarimetric decomposition was used to analyze radar backscattering mechanism from the view point of SAR data. Freeman-Durden technique was used to decompose SAR data that yielded 3 decomposition parameters, which are surface scattering, double-bounce scattering, and volume scattering in the area study. Those 3 parameters were then overlaid to peat reference map for further analysis. It shows that volume scattering and surface scattering were dominant in tropical peatland. Figure 1 describe about polarimetric decomposition using Freeman-Durden technique, which describe 3 backscattering mechanisms, those are double-bounce scattering (R), volume scattering (G), and surface scattering (B).

3.2. Shrub Class Extraction

Table 1 shows class combination which represents shrub class in land use/cover reference map. Based on the results of overlapping with land use/cover reference map, 5 class combinations were obtained.

Accuracy assessment using error matrix was conducted in 1,292 sample points to obtain a combination class which represents shrub class in land use/cover reference map the most. Those class had the most significant accuracy parameters, which were producer's accuracy (PA), user's accuracy (UA), overall accuracy (OA), and Kappa coefficient (Ks) that was shown in Table 2.

Table 2 shows that more than 70 percent of PA was obtained for all classes, where class coded f5 yielded the highest PA of 89.4 percent. All classes yielded more than 60 percent of UA, where classes coded f2 yielded the highest UA of 85.8 percent. Meanwhile the highest OA was obtained for class coded f4, which is 76.3 percent. Class coded f4 yielded the highest Ks of 0.2435.

3.3. Peat Class Extraction

RVI was derived from backscatter data (σ0) using a formula proposed by Kim and van Kyl (2001). Generally, RVI ranges between 0 and 1, which estimates biomass amount from SAR data.

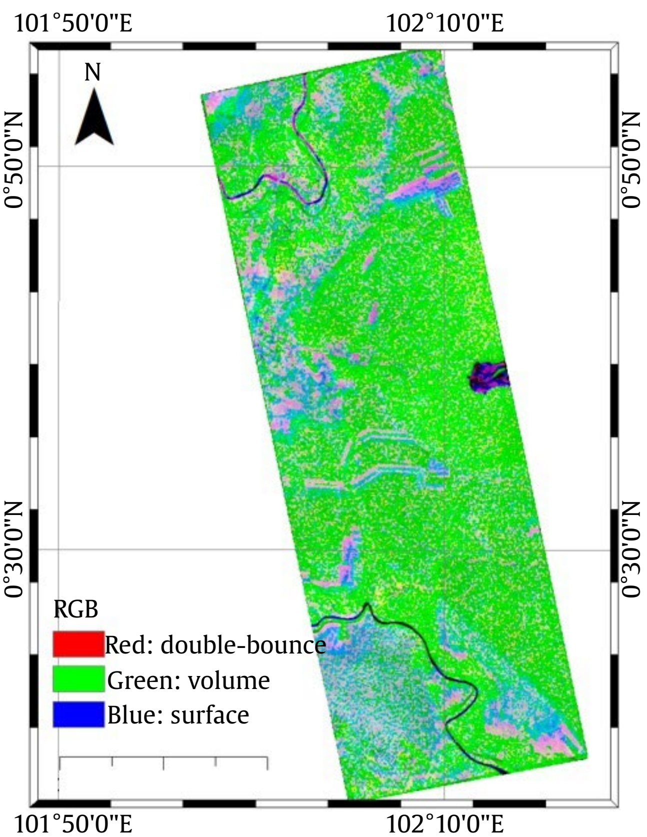


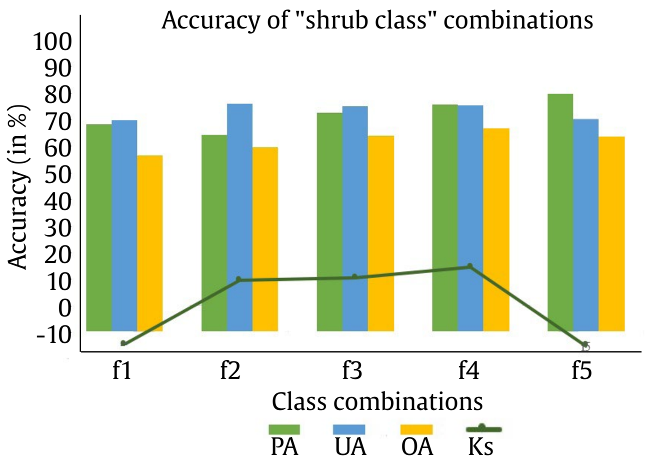
Figure 1. Polarimetric decomposition using Freeman-Durden technique, which describe 3 backscattering mechanisms: double-bounce scattering (R), volume scattering (G), and surface scattering (B)

Table 1. "Shrub class" combinations

Class combination	Code
3-5-8	f1
3-7-8	f2
3-7-8-10	f3
3-4-7-8-10	f4
3-4-5-8-10	f5

Table 2. Accuracy parameters of 5 class combinations

	Class combination				
	f1	f2	f3	f4	f5
PA (%)	78.1	74.0	82.2	85.4	89.4
UA (%)	79.5	85.8	84.7	85.2	79.8
OA (%)	66.2	69.3	73.8	76.3	73.2
Ks	-0.0472	0.1946	0.2016	0.2435	-0.0522



In this research, RVI ranges between 0.0019 and 3.21123, where non-vegetation area (such as open area, water) yielded relatively low RVI. Meanwhile, RVI that is too high was assumed as blunder.

RVI was then analyzed by overlaying it to peat reference map, which yielding average RVI of 0.852 for peatland and average RVI of 0.791 for non-peatland. Based on the results, RVI was classified into 3 classes based on its standard deviation. Interval classes are narrow-interval class, medium-interval class, and broad-interval class as shown in Table 3.

Narrow-interval RVI had 38,292 percent of data (avg ± 0.5 std dev). Medium-interval RVI had 68,268 percent of data (avg ± std dev). Broad-interval RVI had 95,450 percent of data (avg ± 2 std dev). It means that the broader interval class was, the more data that is included. Classified RVI class was then integrated with selected "shrub class" f4. Integration between RVI and selected "shrub class" was extracted as peat class.

Integration was then overlaid to peat reference map for accuracy assessment. Accuracy assessment was conducted in 1,292 sample points using error matrix. The best integration was extracted as peat class, and the RVI was selected as the best RVI class, which can represent peatland in Siak Regency, Riau Province.

As shown in Table 4 that the broader RVI class interval was followed by the increasing of PA, as well as OA. Meanwhile the broader RVI class interval was followed by the decreasing of UA. Above all, the medium class interval yielded the highest Ks of 0.1079.

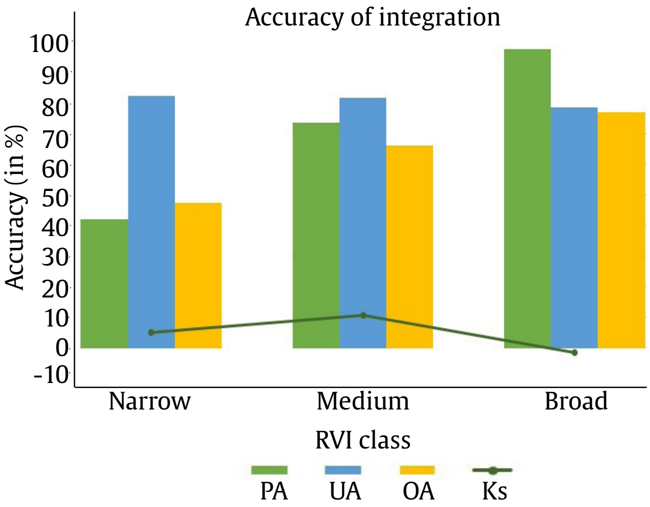
Based on the results, the best integration of the selected "shrub class" and RVI that yielded the most significant accuracy parameters, which were 73.5 of PA, 81.6 of UA, 66.1 of OA, and 0.1079 of Ks. Therefore, medium class interval of RVI was selected as the best integration. Meanwhile, broad class interval of RVI yielded relatively high PA, UA, and OA, yet relatively low Ks. Narrow class interval of RVI also yielded relatively high OA, yet low PA, UA, and Ks.

Table 3. RVI classification

RVI class interval	Range
Narrow	avg ± 0.5 std dev
Medium	avg ± std dev
Broad	avg ± 2 std dev

Table 4. Accuracy of integration

	RVI class interval		
	Narrow	Medium	Broad
PA (%)	42.0	73.5	97.6
UA (%)	82.4	81.6	78.6
OA (%)	47.3	66.1	77.1
Ks	0.0524	0.1079	-0.0160



4. Discussion

Tropical peatland in Siak Regency, Riau Province can be identified by integrating radar backscattering mechanism and medium class interval of RVI, which both were derived from L-band SAR data (ALOS PALSAR). Radar backscattering mechanism was then analyzed and shows that volume and surface scattering was dominant in Siak Regency because of the presence of vegetation and open area. The overlay of 3 decomposition parameters of SAR data and peat reference map had been used for identify tropical peatland. The overlay result showed that volume scattering and surface scattering were dominant in tropical peatland.

Unsupervised classification ISODATA was conducted to derived class that represent the shrub class on the reference map. The most significant shrub class was selected by assessing its accuracy using error matrix, which was class coded f4 (3-4-7-8-10). Later on, spatial analysis was conducted by overlaying RVI and peat reference map and a relationship was found between RVI and tropical peatland. RVI in tropical peatland tend to have higher average value of RVI than non-tropical peatland. Integration between selected "shrub class" and RVI was performed to extract peat class. The best peat class was selected from integration between shrub class f4 and medium class interval of RVI.

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