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Application of Polarimetric Decomposition and Interferometric SAR Using ALOS-2 PALSAR-2 Data to Detect Potential of Combustible Peatland Areas

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Abstract— Forest fire in Indonesia occurred mostly in peatland area when the peatland areas were dried with groundwater table more than 40 cm. This peatland condition has become degradation areas with high potentials to fire. Some previous research utilized optics data remote sensing to detect the potential combustible peatland area while others concerned on backscattering information of synthetic aperture radar data compared with Forest Fire Danger Rating System (FDRS) data to identify a peat fire risk area. Peatland is prone to fire, usually associated with land that is open, close to the road, and dry conditions. In this research, polarimetric decomposition and interferometric SAR techniques have been used to determine the potential of combustible peatland area. Polarimetric Decomposition is easier to use to recognize open peatland areas. Besides that, it can also be used to identify roads and canals in peatland areas. Based on the research carried out this time, by implementing the Yamaguchi three-component model-based decomposition, we easily distinct areas that are exposed to peatlands. The dominant surface scattering marks open spaces. By using interferometric SAR technique, we also easily map areas experiencing subsidence. Regions that experience subsidence in peatland areas are usually dry areas with low groundwater conditions. Based on the results of interferometric synthetic aperture radar by using ALOS-2 PALSAR-2 data, subsidence conditions have been found in this area of peatland. SAR ALOS-2 PALSAR-2 image acquired on May 9, 2015, is used as master image and image received on March 25, 2017, is used as a slave image. Phase interferogram generated with multi-looking 5×5 pixels, Goldstein filtering 5×5 pixels, and normal baseline -43 m, and H-ambiguity 1049.4. Annual subsidence rate average was 2.8 cm/year, minimum 2.5 cm/year, and a maximum of 3.5 cm/year. The subsidence rate then converted to groundwater level information based on Woosten model and validated by using groundwater table measurement from the field. The simulation of groundwater table in average is 69.4 cm, with minimum value 63 cm and maximum value 87 cm. Based on validation and compared to the field data with correlation 0.85, and the area confirmed as high potential of combustible peatland area.

1. INTRODUCTION

In the global area, peatland occupies around 3%, with 89% of which spreads in the northern hemisphere area while the others occur in the tropics area. In the northern hemisphere area, peatland is formed in low-relief, under high precipitation-low temperature climatic regimes, spreading in Russia, North America, and Europe. The others cover in the tropics area, where peat is formed under high precipitation-high temperature condition, spreading mostly in Southeast Asia but also in East Asia, the Caribbean and Central America, South America and Africa [1].

Indonesia has the largest peatland area in Southeast Asia (47%), besides Malaysia (6%), Papua New Guinea (3%), and smaller area amounting 1% spreading in Brunei, Myanmar, Thailand, and Vietnam [2]. Indonesia has around 14.91 hectares of peatland is spread out in Sumatera with 6.44 million hectares (43%), Kalimantan with 4.78 million hectares (32%), and Papua with 3.69 million hectares (25%). Peatland in Sumatera mostly located in Riau, Sumatera Island (60.1%) [3].

Forest fire is the main problem in Indonesia. Starting in 1982, 75% of the forest fire occurred in peatland area, and mainly in open area [2]. Almost 27.5 million ha of forest had changed into logging, fires, and timber, pulpwood and palm oil plantations between 1990 and 2015, and now of the 75%, only 50% area remains covered in the forest. The worst of forest fires occurred in 1997/1998 and 2006 during El Nino with 140.000 hotspots. The similar condition occurred in 2015 when forest fire started at the end of June 2015. The fire in peatland areas then could only be stopped after the start of the rainy season in November 2015 [2].

The Canadian Forest Fire Danger Rating System (FDRS) was installed in Indonesia starting from 2004 [2] and very important to support study related to a forest fire. There are research potentials to detect combustible peatland areas by using comparison between optical sensor and microwave remote sensing data. A variety of large scales of the pattern of fuel connectivity can be used for monitoring pattern of fire danger based on a combination of remote sensing approach and graph theory by using optic sensor MODIS satellite data. NOAA-AVHRR also successfully as input in soil moisture detection and understanding as an indicator of fire danger [2]. Synthetic aperture radar also has ability as an input to detect the potential of combustible peatland area based in soil moisture retrieval method [4, 5].

Combustible peatland areas mostly in open space, in the dry session when groundwater table more than 40 centimeters. Groundwater table of peat land drop in the dry season because many drainage canal developed due to the interests of developing plantation areas [3]. SAR polarimetric target decomposition concept has been very well developed, it is used to separate surface scattering, volume scattering, double bounce scattering, and helix scattering [6]. The Yamaguchi three-component model-based decomposition is one of the model-based decompositions, which is easy to apply to recognize open areas and drainage canal in peatland areas.

Interferometric SAR also has high ability to detect land deformation as subsidence and uplift movement, based on twin of images or multi temporal images [7]. Beside land deformation, this application also very powerful to detect flood inundation area in rural and urban area [8, 9]. Since there is relationship between subsidence phenomenon and groundwater table condition in the peatland areas [2], Interferometry SAR also effective to detect potential of burned peat areas. This paper explained how polarimetric decomposition and interferometric SAR can complement each other in an effort to detect of potential combustible peatland areas as apart of peatland restoration supporting in Indonesia [10].

2. RESEARCH AREA

The research area is located in Sungai Apit, Siak Regency, Riau Province, Indonesia. The coordinate position is from latitude 1°16′30″ until 0°20′49″ and longitude 100°54′21″ until 102°14′50″. Siak has weather temperature between 25°–32° Celsius.

Siak Regency is apart of Riau Province, where mostly consist by peatland area. In this research area, the topographic indicated that the peat deposits type is peat domes with the maximum peat thickness is about 13 meters [11].

3. METHODOLOGY

3.1. Synthetic Aperture Radar Data

This research used the scene of SAR satellite data ALOS-2 PALSAR 2 provided by Japan Aerospace Exploration Agency (JAXA).Three images of ALOS-2 data were on May 9, 2015, March 25, 2017, and August 2, 2017 to be processed in this research.

3.2. Field Survey

Field survey have been carried out from July 26 to August 10, 2017. Positions were measured by A Differential Global Positioning System (DGPS) Leica 1200+. Groundwater table measured for each points sampling, where the points sampling shown in Fig. 1.

3.3. Image Processing and Analysis

In this research, the Yamaguchi three-component model-based decomposition employed to detect open area and drainage canals in peatland areas by using ALOS-2 PALSAR-2 data were on August 2, 2017. This research also employed Interferometric Synthetic Aperture Radar method based on interferogram that developed from a coherence technology of active radar imaging by using ALOS-2 PALSAR-2 data were on May 9, 2015, and March 25, 2017. Flowchart of research shown in Fig. 2.

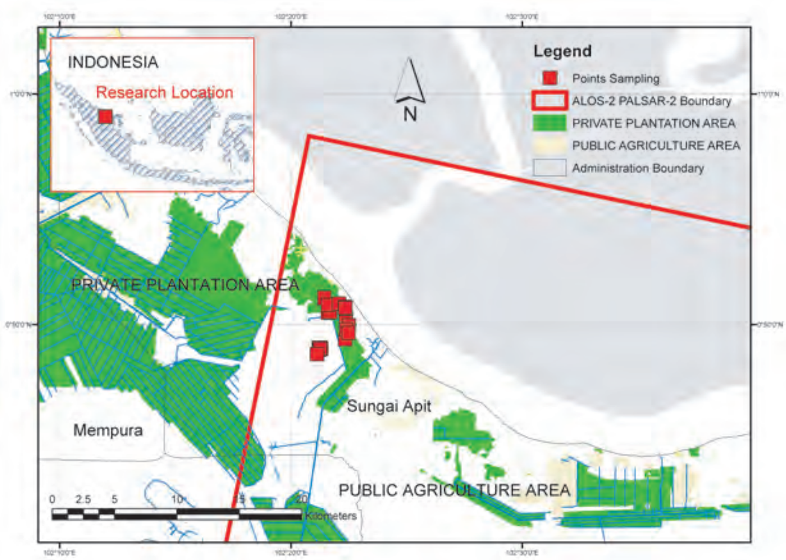


Figure 1: Research location.

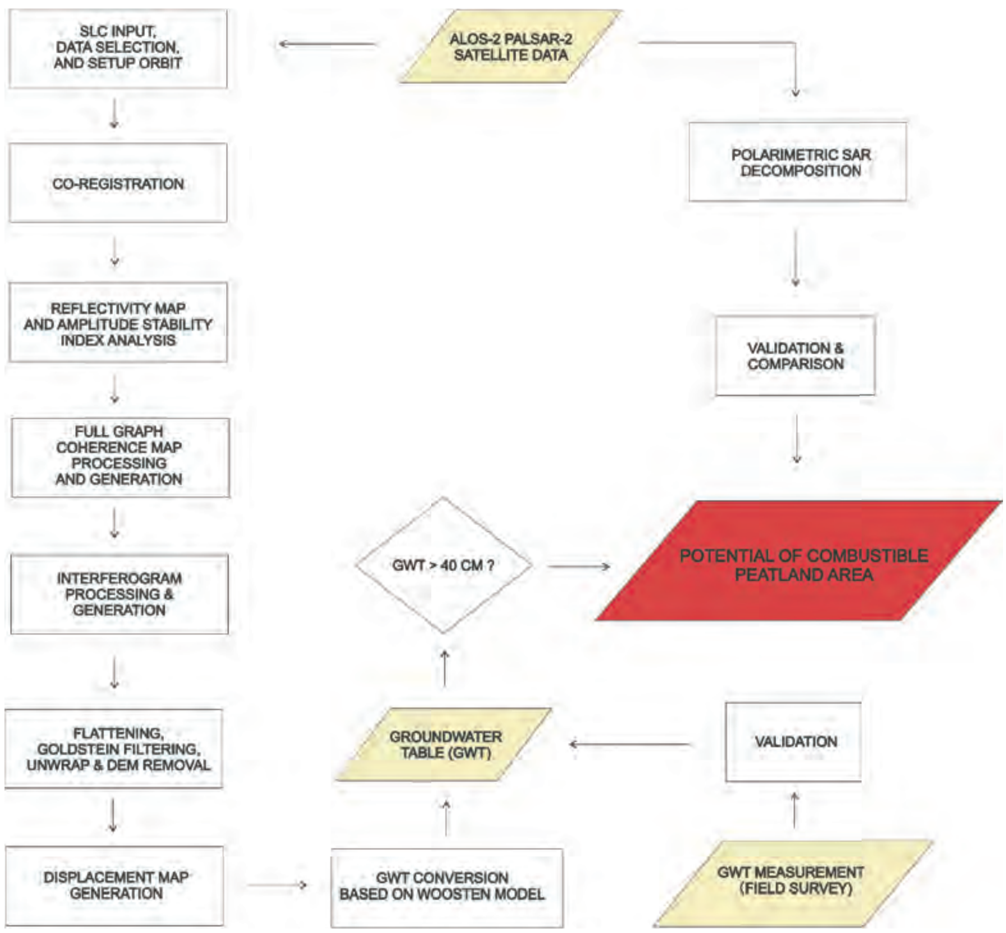


Figure 2: Flowchart of research.

Groundwater table simulation then calculated by using Woosten Model [2] based on Eq. (1)

$$S = 0.04 * GWT \tag{1}$$

where S is annual rates subsidence (cm/year) and GWT is groundwater table depth (cm).

Coefficient correlation between groundwater table based on simulation by using Interferometric

Synthetic Aperture Radar and based on measurement in the field area calculated by using Pearson correlation coefficient. Based on simulation and validation, the area that has GWT more than 40 cm is classified has the potential of combustible peatland areas.

4. RESULT AND DISCUSSION

The Yamaguchi three-component model-based decomposition employed to identify an open area and also drainage canal areas of peatland. The image of Yamaguchi Decomposition Result of SAR images August 2, 2017, shown in Fig. 3. RGB composite image generated based on configuration double bounce scattering for the red color, volume scattering for the green color, and surface scattering for the blue color.

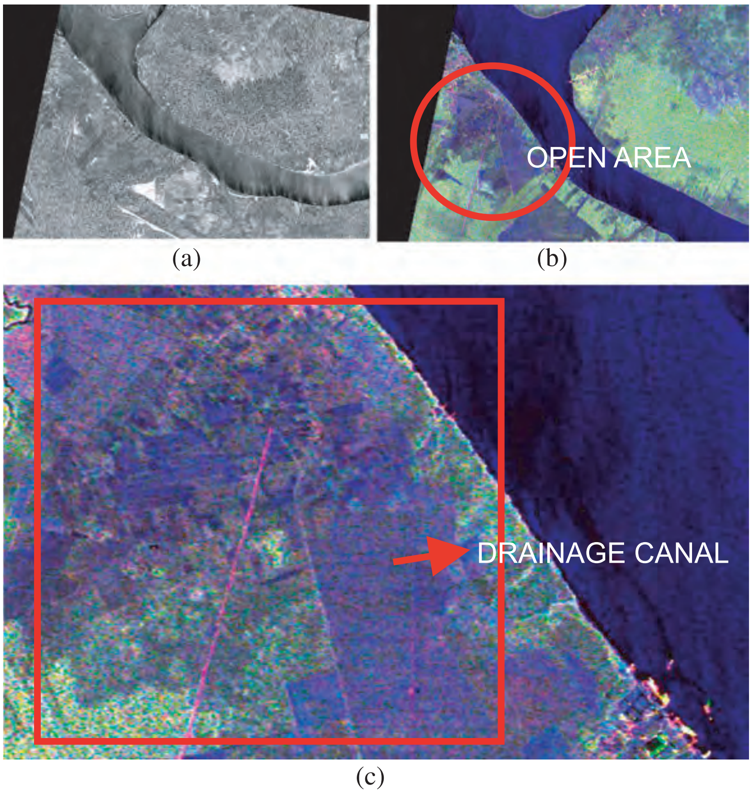
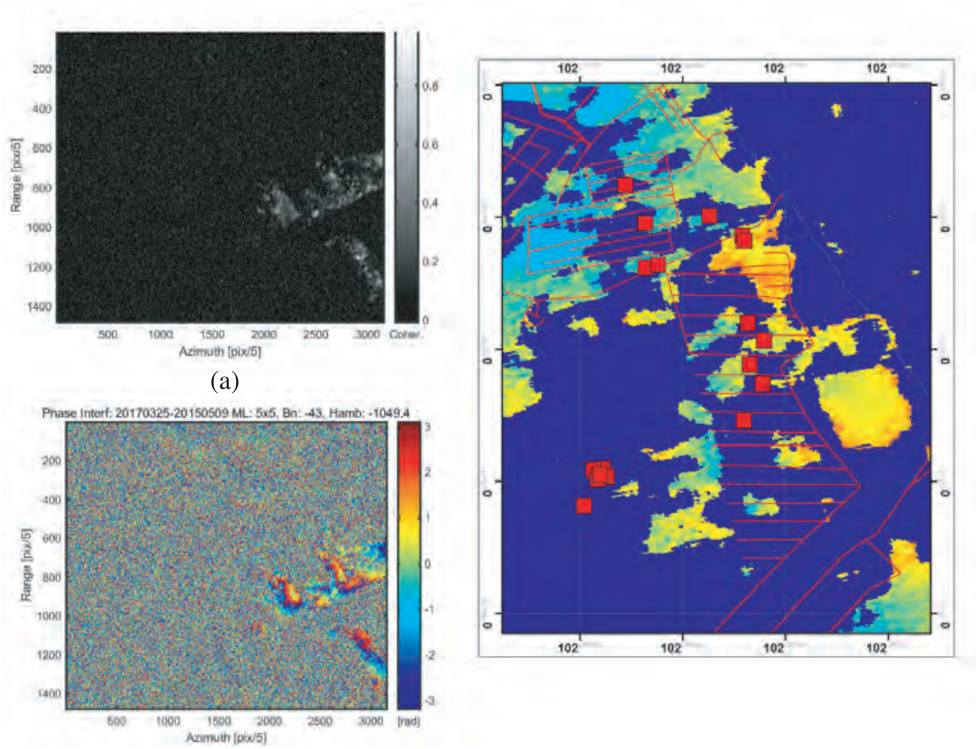


Figure 3: The Yamaguchi three-component model-based decomposition result of ALOS-2 PALSAR-2 data, where: (a) surface scattering, (b) open area of RGB composite of double bounce scattering (Red), volume scattering (Green), and surface scattering (Blue), and (c) drainage canal in the peatland areas.

By applying the Yamaguchi three-component model-based decomposition, the open area and canal drainage can be easily recognized. The open area of peatland is shown in blue on the RGB composite image. Irregular lines with dark colors show drainage canals, and regular red lines indicate the roads around the canal due to the dominance of the double bounce scattering. Canal and roads are associated with flammable peatlands, related to human intervention on peatlands.

Based on the results of interferometric synthetic aperture radar by using ALOS-2 Palsar-2 data, subsidence conditions have been found in this area of peatland. We used image acquired on May 9, 2015 as master and image acquired on March 25, 2017 as a slave. Phase interferogram developed with Multi Looking 5×5 pixels, Goldstein Filtering 5×5 pixels, and Normal Baseline -43 m, and H-ambiguity 1049.4. Annual subsidence rate average was 2.8 cm/year, minimum 2.5 cm/year, and maximum 3.5 cm/year. Result of the SAR interferometry process shown in Fig. 4. Then, groundwater table simulation is calculated based on subsidence by using Woosten models, and the results can be seen in Table 1.

Groundwater table is an important indicator in the term to detect peatland degradation. Regulation in Indonesia mentions that peatland that has groundwater table more than 40 cm is under the degradation condition [31]. Based on previously research, when groundwater table drops under 40 cm, soil moisture will decrease from 0.9 cm^3/cm^3 at saturation to about 0.50 cm^3/cm^3 at a pressure head of -4 kPa [2]. This condition will lead to burned peat spreading quicklyv [2]. In



(b) (c)

Figure 4: Result of interferometric SAR analysis.

this survey, the groundwater table was measured from the canals or holes near the point sampling. Average groundwater table conditions from 18 points sampling are 87.33 centimeters, minimum 65 centimeters, and a maximum 102 centimeters as shown in Table 1.

Table 1: Coordinate position, GWT, and GWT simulation.

Point Sampling	Latitude degree	Longitude degree	GWT cm	GWT Simulation cm
1	0.83492	102.37277	84	-
2	0.83273	102.37481	68	63
3	0.82263	102.37227	65	80
4	0.82965	102.37302	86	79
5	0.82721	102.37461	87	-
6	0.85234	102.35321	101	-
7	0.81651	102.35446	88	-
8	0.81551	102.35495	88	-
9	0.81636	102.35321	88	82
10	0.81511	102.35376	88	87
11	0.81576	102.35406	88	-
12	0.81183	102.35207	87	-
13	0.84194	102.35983	81	-
14	0.84274	102.36142	87	-
15	0.84751	102.35978	82	-
16	0.84846	102.36789	100	84
17	0.84592	102.37207	102	-
18	0.84527	102.37232	102	81

Simulation of groundwater table shows the area has more than 40 centimeters. Correlation between the simulation of groundwater table and groundwater table based on the field survey then compare by using Mac Pearson's correlation test for validation. Based on a correlation test between simulation groundwater table and field survey gave a correlation coefficient (R) value 0.85 and determination coefficient (R2) 0.73. Graph of the test shown in Fig. 5. It is shown that the correlation between between ground water table and ground water table simulation is high.

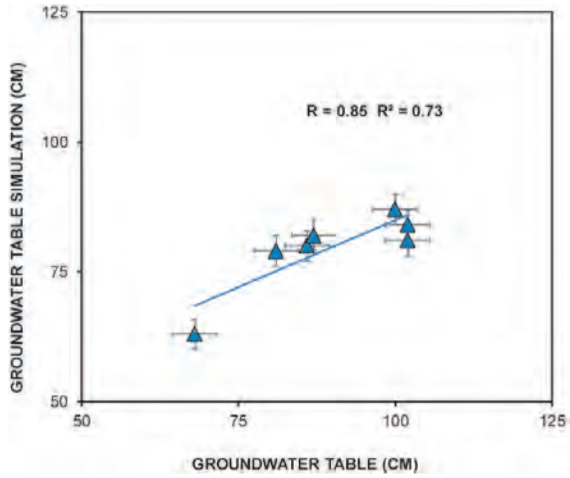


Figure 5: Correlation graph between groundwater table and groundwater table simulation based on InSAR analysis.

In this research, it is showing that both of polarimetric decomposition and interferometric SAR can mutually reinforce as a basis for determining potential combustible peatland areas. Polarimetric decomposition can be used to detect open areas and drainage canals on peatlands Polarimetric decomposition can be used to detect open areas and drainage canals, and SAR interferometry can be used to simulate ground water table conditions on peatlands which are also associated with the potential for fire ease.

5. CONCLUSION

Polarimetric decomposition and interferometric SAR can be complement each other to detect the potential of combustible peatland areas. Based on polarimetric decomposition SAR ability to identify open areas and drainage canals, and interferometric SAR ability to simulate groundwater table condition, detection of the potential combustible peatland areas will give the high significant interpretation.

ACKNOWLEDGMENT

This work partially funded by the Josaphat Microwave Remote Sensing Laboratory (JMRSL), Chiba University, and the Ministry of Research, Technology and Higher Education Republic of Indonesia, through its scholarship for Program Research and Innovation in Science and Technology (RISET-Pro) World Bank Loan No. 8245-ID. The authors would like to acknowledge to Siak Regency Local Government, Universitas Islam Riau, Republic of Indonesia, and SARPROZ developer software.

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