A Satellite-Based Early Warning System for Peatland Fires Toward Sustainable Palm Oil in Indonesia

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ABSTRACT

Peatland fires in Central Kalimantan occur almost every year with an average of 15,000 hotspots or approximate 62% of the total fires in Kalimantan, Indonesia. The impact of these fires could very detrimental to the palm oil agroecosystem, such as damage on soil, obstacle plant photosynthesis and decreases the visibility of transportation. It will be downgrade oil palm production and its distribution. So far, Central Kalimantan has been no fire prevention system particularly for oil palm agroecosystem in peatland. This study is important to be done for prevention the occurrence of severe fires. The objectives of this study are to analyze fire severity using hotspot data of MODIS (*Moderate Resolution Imaging Spectroradiometer*), to examine the satellite images and the field-based of biophysical data (weather, land use, soil properties), to investigate the perception of local communities regarding to palm oil agroecosystem in peatland, and to develop the GIS (*Geographic Information System*) databases for fire warning. Study result proposes an integrated fire early warning system using Peatland Fire Risk Index (PFRI). There are some benefits of this research such as to reduce the release of emission, to minimize the loss of peat layers, and to prevent the high cost of peatland fire suppression. This technology will be one of guidelines for the implementation of the ISPO *(Indonesia Sustainable Palm Oil)* certification in Central Kalimantan.

KEY WORDS: *fire early warning, MODIS, palm oil, peatland fires, sustainable agriculture*

INTRODUCTION

Indonesian archipelago has large not only tropical rainforest but also peatland in Southeast Asia (FAO, 2011; Wetland, 2004). However, one of the adverse effects of rapid deforestation and land degradation on peatland was the uncontrolled forest and peat fire that occurred prior to the period of 2014. Central Kalimantan in Kalimantan has recorded as a part of fire prone areas in Indonesia or approximate 62% of the total fires in Kalimantan (Yulianti and Hayasaka, 2013). The level of air pollution in central burning area and its vicinity was very high and toxic for human (Hayasaka et al. 2014, Yulianti, 2011). As a result, higher amounts of carbon dioxide (CO_2) emission as well as haze inter boundaries caused serious disaster throughout human history.

Thousands of hotspots detected by MODIS sensor each year particularly on peatland, which some started from oil palm plantations in Kalimantan and Sumatra (Yulianti et al, 2013). Distribution of palm oil in Central Kalimantan is shown in Figure 1. So far, no effective fire prevention for oil palm agroecosystem had established in peatland areas. It is important to develop fire early warning system for sustainable oil palm. Remote sensing technology is the best way to provide data hotspots with a high confidence level but relatively low cost. Since 2002, MODIS becomes new fire sensor that provides update hotspot data and imagery across the world including Indonesia (Yulianti and Hayasaka, 2011a). To simplify the management of data and satellite imagery on spatial scale, GIS is one of best methods such an example in Yulianti and Hayasaka (2011b). The information can be distributed quickly to a fire fighter or related parties via an electronic telecommunication device e.g. smart mobile phone (smartphone). GPS (Global Positioning System) in the smartphone can also help recording the position of the fire and send to data center. Thus, the development of technology with integration of remote sensing, GIS and information telecommunication (IT) expected to generate a fire early warning effectively.

This study is first stage of whole project, which mainly collected bases data. The aim of study are to analyze fire severity using hotspot data of MODIS data, to examine the satellite images and the field-based of biophysical data (weather, land use, soil properties), to investigate the perception of local communities regarding to palm oil agroecosystem in peatland, and to develop the GIS databases. The early prediction of risks fire can be an effective prevention in the field. It can be supports zero burning concept, as one of the ISPO standards. The final result of this project supposed to be engaged with policy maker, Plantation Agency of Central Kalimantan Provincial and implemented by selected plantation.

METHODOLOGY

Study area

The study covered the area from north latitude 0.45^o to south latitude 3.50^o and from east longitude 110° to 116°. A map of the area of the study, the whole of Central Kalimantan, Indonesia, with the palm oil and peat

distribution superimposed, is shown in Figure 1. There were 13 regencies and 1 capital city, namely Gunung Mas, Murung Raya, Barito Utara, Lamandau, Barito Timur, Sukamara, Barito Selatan, Kotawaringin Barat, Seruyan, Kotawaringin Timur, Kapuas, Katingan, Pulang Pisau and Palangka Raya. The total area of the study region is about 150.000 km^2 (BPS Kalteng, 2011), with about 20% of the area covered by peatland. Coastal peatland is distributed from the western area of Pangkalan Bun in Central Kalimantan to the Kuala Kapuas near Banjarmasin in South Kalimantan. Katingan, Pulang Pisau and Kapus Regency have the largest (> 4.000 km^2) and the deepest (> 400 cm) coastal peatland, where some are covered by Sebangau National Park and Borneo Orangutan Survival area. Inside the peatland, there are tens of the palm oil concessions (WWF, 2006) and they are mostly expansion from nearby the non-peatland area (Figure 1).

Data and methods

Daily MODIS hotspot data (Collection 5.1 active fire product) for 2002 to 2012 were used in this paper. Recently, MODIS data has been extracted automatically through the FIRMS website (Fire Information for Resources Management System, https://earthdata.nasa.gov/data/near-real-time-data/firms).

Monthly precipitation data was extracted from full daily weather data measured at Palangkaraya Airport (Tjilik Riwut, 2.23°S, 113.95°E), which is about 100 km from the nearest coastline. To define conventional El Niño, La Niña, and normal conditions related to drought, monthly NOAA Oceanic Nino Index (ONI) for the recent 10-year (2002-2012) was used in this analysis. There was 3-month running mean of Sea Surface Temperature Anomalies (SSTA) in the Niño 3.4 region (N5°-S5°, W120°-170°). The changes of ONI data was obtained from satellite of NOAA Climate Prediction Center website.

The measurement point of ground water level (GWL) located at 2.32°S and 113.90°E on the upper catchment of River Sebangau about 800 m from the forest edge and 2 km from the river along the logging railway at the right bank of the Sebangau River. The ground water level was measured with a pressure sensor and data logger (1993-2000:Druck Ltd, PDCR830 and Kona System, Kadec-Mizu, 2000-2008:STS DL/N).

Landsat-7 ETM+ images (path 118/row 62) were selected from several years prior to 2014. Land cover map for a part of Central Kalimantan classified from these images with maximum cloud covers 10%. To encounter striping caused by the failure of the scan line corrector (SLC) in 2003, this study minimized during the process of image classification.
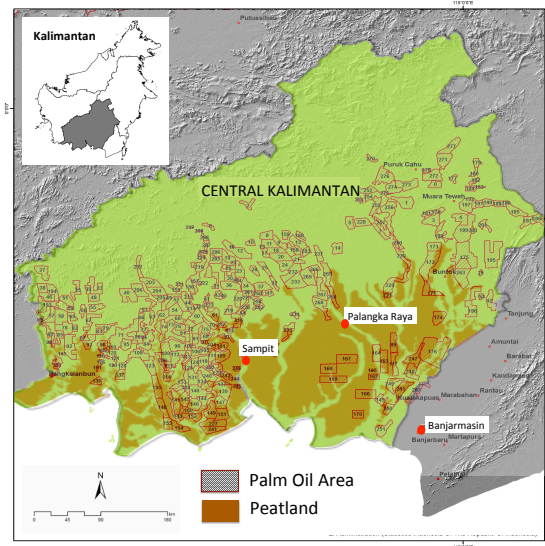

Figure 1. Palm oil and peatland area in Central Kalimantan

RESULTS AND DISCUSSION

Fire activity in peatland under dry conditions

In Table 1, the average peatland fires showed in El Nino and La Nina events (NOAA definition). Severe fire occurrences in peatland during (>1,000 hotspots) were observed in Kapuas and Pulang Pisau Regency under the dry conditions arising from the El Niño event with ONI (Ocean Niño index) values in NDJ greater than +0.5. There is a strong relationship between fire activities and the lack of accumulation precipitation in July, August and September (Figure 2). Third higher of peatland fire occurred in Kotawaringin Timur Regency. It is evident that most

fires are related to agriculture activity, and this is consistent with Kotawaringin Timur Regency being home to the most prolific cultivation of palm oil in Central Kalimantan (440.000 ha, Table 1).

Table 1. Summary of peatland fire activities (hotspot) in the regencies of Central Kalimantan

No	Regency	Area (.10³ha)			Average fires (hotspots) in peatland		Average fires density (hotspots/(yr.10⁻³ha))	
		peatland[a]	non-peatland[b]	Palm oil[b]	El Nino years[c]	La Nina years[d]	El Nino years	La Nina years
1	Barito Selatan	228.00	883.00	15.00	406.25	65.75	1.78	0.29
2	Barito Timur	39.00	383.00	7.50	46.25	12.25	1.19	0.31
3	Barito Utara	0.30	830.00	20.00	0.00	0.00	0.00	0.00
4	Gunung Mas	0.00	1,080.00	7.50	0.00	0.00	0.00	0.00
5	Kapuas	439.00	1,499.00	34.00	1,239.25	133.25	2.82	0.30
6	Katingan	536.00	1,780.00	54.00	495.00	18.25	0.92	0.03
7	Kotawaringin Barat	282.00	1,076.00	167.00	327.75	44.00	1.16	0.16
8	Kotawaringin Timur	342.00	1,650.00	440.00	651.25	88.00	1.90	0.26
9	Lamandau	0.70	641.00	53.00	0.25	0.00	0.36	0.00
10	Murung Raya	0.00	2,370.00	0.04	0.00	0.00	0.00	0.00
11	Palangkaraya	118.00	240.00	0.20	272.00	30.25	2.31	0.26
12	Pulang Pisau	640.00	900.00	12.00	1,900.00	414.25	2.97	0.65
13	Seruyan	325.00	1,640.00	241.00	611.50	45.00	1.88	0.14
14	Sukamara	104.00	383.00	51.00	296.75	27.75	2.85	0.27
	Total	3,054.00	15,355.00	1,102.24	6,246.25	878.75	20.15	2.66

Note: [a] Wetlands, 2004
[b] BPS Kalteng, 2011
[c] Defined by NOAA (National Oceanic and Atmospheric Administration); ONI $\geq$ +0.5
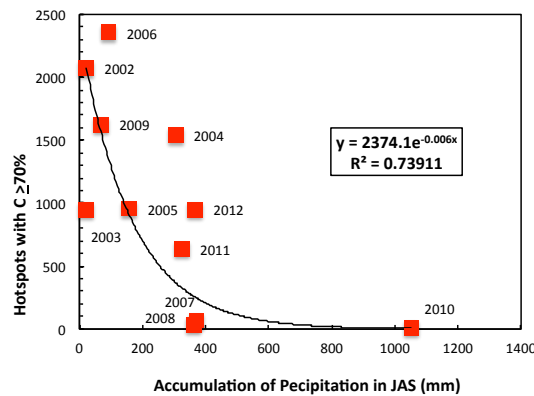[d] Oceanic Nino Index (ONI) $\leq$ -0.5

Figure 2. Relationship of fire activity in Pulang Pisau Regency and accumulation precipitation in the driest months (JAS), Central Kalimantan

Ground water level and fire activities

Figure 3 shows that the average 10-day of GWL decreased to below soil surface from the late May data and reached a critical point (-40 cm, Putra and Hayasaka, 2011) from the early of September. In dry condition under El Nino, the GWL tends to decrease earlier (middle of August) and longer (3-month) from annual trend. The lowest daily mean value was -53 cm for recent year (2002-2011) and -68 cm for severe fire years (> 1.500 hotspots in Figure2). This lowest period coincided with the peak fire period in whole of Mega Rice Project (MRP), where located in southern of Central Kalimantan as discussed in Yulianti and Hayasaka (2013). Under these long-lasting dry conditions, fires could continue by smoldering under the ground of peat layer. Thus, peat fire cannot be suppressed easily until the GWL arise in rainy season (Usup et al. 2004).
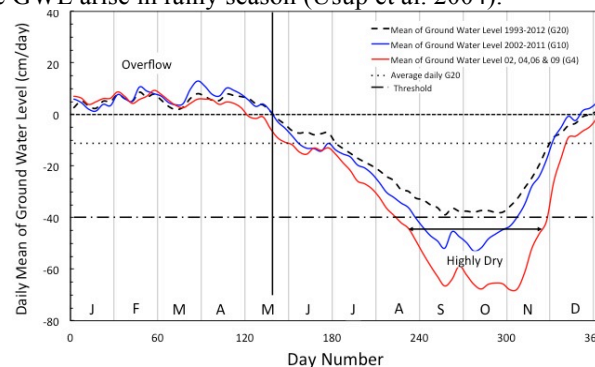

Figure 3. GWL trends

Fire-affected area (deforestation and de-vegetation)

During 2002-2012, the annual fire in Pulang Pisau had a significant variation (~1.500 hotspots) between El Nino and La Nina events (Table 1). Figure 2 shows fire in 2006 is the most severe fire in this regency. It was mostly due to fire occurrences in block C of MRP (~50% of total Pulang Pisau area) as show in Figure 4. To clarify one of the adverse effects of fire, we compare the result of land cover change from Landsat ETM+ and hotspot from MODIS. Figure 4 indicates the largest area of deforestation (red color, Figure 4a) have a corresponding with the dense fire in 2006 (blue box and its vicinity, Figure 4b). There is also evidence to suggest that the area with experiencing fire-driven deforestation in 2006 is still the remaining mixed peat swamp in 2005 as shown in Hoscillo et al (2011). However, this study has not calculates how many the extent of forest and vegetation losses during the incidence.
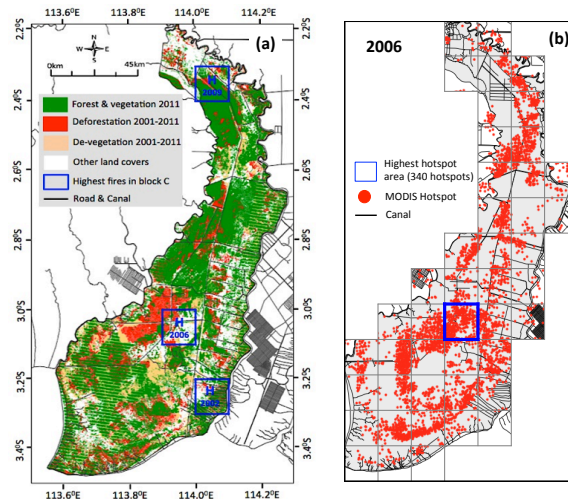

Figure 4. (a) Forest, vegetation, deforested, and de-vegetated area in the MRP area of southern Pulang Pisau Regency (2001-2001); (b) Hotspot distribution in 2006

PFRI-based for future early warning

In Figure 5, future fire risk map for Central Kalimantan made similar to Yulianti and Hayasaka (2013) with additional data from precipitation (Figure 2), ground water level (Figure 3), land cover (Figure 4) and peat conditions. The weekly relationship between fire and its factors influencing will be shown in the equation such:

$FPRI_n = P wn.Gw_n.Epo.Pi$

which, FPRI is Peatland Fire Risk Index

  Pwn is 10-days precipitation

  Gwn is 10-days ground water level

  Epo is constanta evapotranspiration in Summer Dry Season (S_D)

  Pi is peat properties index in S_D

Further, this Peatland Fires Risk Index (PFRI) will be proposed as basic early warning particularly for palm oil agroecosystem. Although human activity is a significant factor influencing fire, climate anomalies and bio-physical factors are more scalable to predict the future catastrophic fires. These data to user via an electronic telecommunication device and also website.
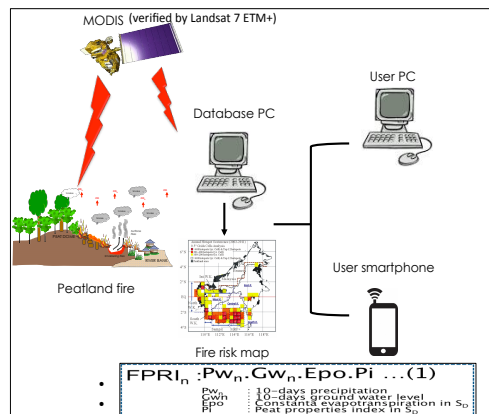

Figure 5. A concept of future early warning for palm oil

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