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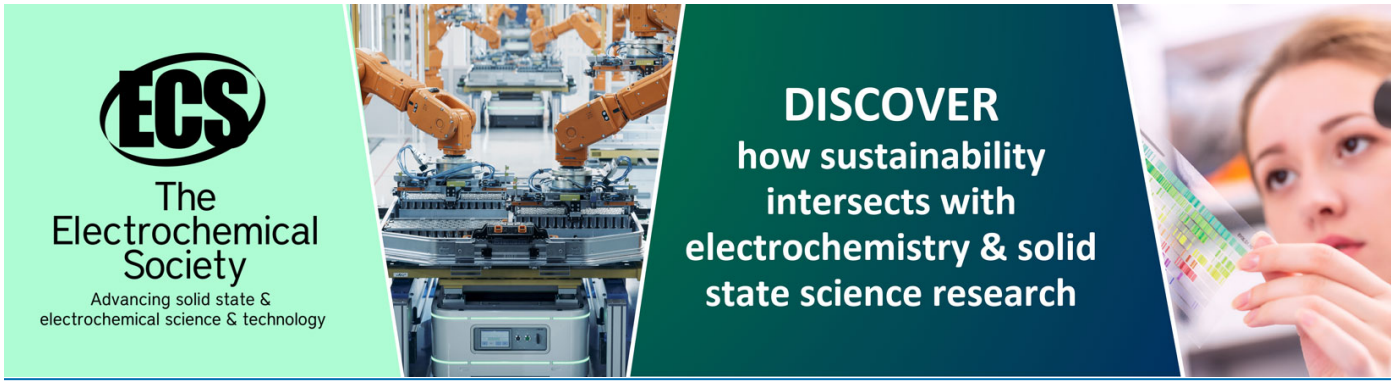

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Developing better understanding on tropical peat fire occurrences and dynamics

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Abstract. Peatland fires are a significant contributor to Indonesia's greenhouse gas (GHG) emissions, particularly during ENSO events, in drained areas, and upon first and second burns. This NASA-funded project will provide the necessary fire emissions research and expertise to increase capability of peatland fire emission quantification. The first three years of the project (2014-2017) focused on the development of methods to assess peat-fire relations and improve peat fire emission calculations, with initial data from the core area; BOSF-Mawas in Central Kalimantan. The second phase of the project (2017-2020) expanding to a national level to better advance Indonesia's capabilities for peatland carbon emissions, increasing the data volume and knowledge in the core area, and on transplanting these methods to other peatland provinces in Indonesia, e.g., Riau and Jambi. Here, we establish and monitor dipwells and subsidence plots in Central Kalimantan, Riau, and Jambi to better understand the effect of hydrology to the peat fire. To better understand the peat fire typology and dynamics, we develop the new method for Fire Scene Evaluation and measured some peat and peat fire properties. This paper compiling the project overview, researches have been done and on-going researches in Central Kalimantan, Riau, Jambi, and Papua provinces, and some essential findings of the project.

1. Project overview

Peatland fires are a significant contributor to Indonesia's greenhouse gas (GHG) emissions, particularly during ENSO events, in drained areas, and upon first and second burns. Each year thousands of hectares of peatland burn in Indonesia emitting tonnes of greenhouse gasses, particulates, and aerosols. Emission calculations for tropical peatlands concerning fire have previously based upon limited field data, as noted in IPCC, and there remains little published field data on peat fire behavior and related carbon loss.

To address this data gap, a joint Indonesian-US project on Peat Fire Research Project was established, funded by National Aeronautics and Space Administration (NASA). Phase I of the project (2014-2017) was hosted by South Dakota State University (SDSU) – IPB University, and University of Maryland Center for Environmental Studies (UMCES) – IPB University hosted the Phase II (2017-2020). This project aimed to explore how and why peatland surface fires transition to smoldering peat fires and how these events might be recognized and characterized remotely. An integral component to this project is the field-based collection of biophysical and social data relating to peat fires.

This NASA-funded project builds upon extensive investments and research, since 2009, in a technical capacity, data collection, and site infrastructure development, initially as part of the Kalimantan Forests and Climate Partnership (KFCP) REDD+ demonstration project. Phase I of the project developed the necessary fire emissions research and expertise to complement the existing decomposition-related emissions monitoring capacity for the BOSF-Mawas Area in Kapuas District in Central Kalimantan.

During Phase II of the project, BOSF continues to collect hydrology and vegetation data as well as Fire Scene Evaluation (FSE), training new partners from Riau, Jambi, and Papua in these methods, and initiate data collection from these new provinces to facilitate nation-wide analysis and understanding.

2. Project Location

The project has been taken in 4 provinces, as follows:

1. BOSF–MAWAS Area, Mantangai, Kapuas District, Central Kalimantan
2. Tanjung Leban Village, Bengkalis Regency, Riau
3. Pematang Rahim and Sinar Wajo Villages, Tanjung Jabung Timur Regency, Jambi
4. Bintuni District, Teluk Bintuni Regency, West Papua.

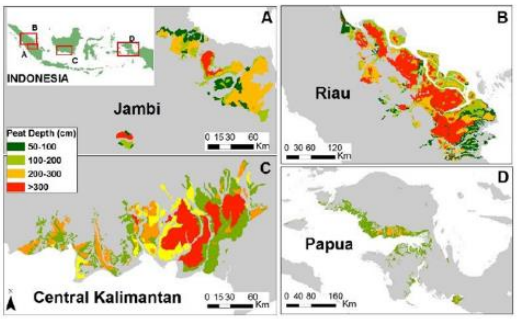

Figure 1. Project location at 4 provinces

3. Activities and Findings

3.1. Vegetation and Hydrology Monitoring

In Mawas Area, Central Kalimantan, Hydrology and peat subsidence monitoring have done during the peak-wet and peak–dry seasons. Water tables were at their most extreme for several years, for both the wet and dry season. The BOSF-Mawas team monitored 300 dipwells, 64 subsidence poles and 34 staff gauges in 21 transects.

Water table depth measured concerning peat surface; thus peat surface elevation (PSE) must be factored into developing the hydrological model for the area. Measuring PSE requires high-tech equipment; thus, BOSF contracted Geoindo during Nov 2016 to measure the PSE for all the dipwell locations, supported in the field by BOSF [1].

In Sumatra, the groundwater level (GWL) monitored for 40 and 69 dipwells in Riau and Jambi, respectively. Forty dipwells were established on three transects in Tanjung Leban Village, Bengkalis Riau by Riau University team and monitored weekly. Jambi University team established 45 dipwells on different land covers in Pematang Rahim Village, while KKI-WARSI monitored the GWL monthly from 24 dipwells in Sinar Wajo Village, Jambi.

Twelve vegetation plots measured in one location. Extensive fuel measurements were carried out at each FSE and along the hydrology transects. The three vegetation monitoring locations and fuel load data established in Mawas Area of (1) center part of Block E, (2) 1 km from the Mantangai River in Block E (3) Block A south, each with 12 permanent monitoring plots. Trees, poles, saplings, and seedlings were re-measured. We focused on re-measuring locations that burned during the 2015 fires – for some plots, this was the first time they burned, fuel load data was also collected. This data shows

the loss to forest density, biomass and diversity, and the increase in fuel, making future fires a higher risk.

Our analysis on the changing groundwater level and precipitation data demonstrate an average 1-month time lag between the period of lowest precipitation and the lowest GWL, provides some ability to predict fire risk in advance of the lowest GWL. Further analysis with Terra/Aqua MODIS hotspot data and Landsat imagery demonstrate that more than 80% of fires occur in areas with GWL less than 20 cm; pointing out the value as a GWL threshold for management activities to lower fire risks of degraded peatlands [2]. We noticed that Nino 3.4 SST Anomalies of any positive value should recognize as significant risk factors for peat fire and initiation of fire prevention efforts as they signify that the driest months are likely to yield significant fire occurrences [3].

3.2. Fire Scene Evaluation (FSE)

The FSE, with field worksheets, was developed and used to assess fires identified utilizing hotspot data and community observations to locate the fires. The FSE involved biophysical observations such as area burnt and fire, peat, and fuel characteristics along with inquiries about the effects of human actions on ignitions and fire types. The FSE used a predetermined format and questions to ensure consistency of results, and are replicable.

These new field methods are designed to undertake 1) in-depth fire scene evaluations including assessments of surface fire intensity, fuel availability and consumption, human actions related to fire causes, and fire-related peat characteristics; and 2) the horizontal and vertical rate of spread of peat fires, volume of peat consumed and linking this information to environmental conditions (peat moisture content at different locations at the face of the peat fire, water table depth, surface fuel loads, peat type and vegetation (available fuel)[4].

These in-depth Fire Scene Evaluations (FSE) result into the collection of bio-physical data (including field weather and environmental conditions, measuring essential fire, fuel and peat characteristics with a focus on tropical peat fires) and social data (namely human actions relating to the fires). The accompanying Peat Fire Behaviour (PFB) data describes in detail how the fire is moving through the peat [5].

The FSE has been done in Mawas area by BOSF during the dry months of 2016 and October 2018, while WARSI conducted FSE in Sinar Wajo Village on September 2019. FSE Field Manual has now been published through IPB publishing house and has distributed to relevant government and academic partners.

3.3. Fire Monitoring

The remotely-sensed and field data showed most of the fires in 2015 were in the south, in the villages of Kalumpang and Mantangai Hulu and were associated with land preparation using fire for palm oil development. Fires along the Mantangai River were associated with hunting while those along the SPI canal were mainly escaped fires from along the Mantangai River. Fires were also evaluated in the vicinity of Tuanan Orangutan Research Area. Evaluated fires ranged from 4 to 50 ha, on peat depths ranging from 1 to 8 m. Roughly half the fires burned some peat. Peat fires were primarily restricted to the “berms” along the canals where the depth of peat burned averaged 16 cm with a forward rate of peat-fire spread of 46 cm/day.

We used satellite data to analyse the fire scar history from 1997 to 2016 for Block A and the surrounding area. Fire seasons were found to extend between July and mid-November, on average, but average fire season lengths have decreased from five to three months over the period of observation. Almost all of the Ex-MRP area has been burnt one or more times, making this area critical for rehabilitation to reduce future carbon emissions [4].

3.4. Development of the peat-fire behaviour methods

In addition to the Fire Scene Evaluation (FSE) methods, field manual, and field worksheets developed in 2015-2014, the project focused on the development of the peat-fire behavior methods in 2015-2016. These methods include assessing the rate of fire spread, peat moisture content ahead of the fire, and peat volume loss. The project's field manual incorporated these methods, and initial data collected n currently under analysis. Our analysis from remote sensing data has allowed initial estimates and maps to create burned areas in the Mawas area 1995-2015

The project has developed a new methodology for estimating both the rate of spread of peat fires and the depth of the burn and associated water table depths and peat moisture content. These measurements will enable estimates of peat consumed from fires and associated GHG emissions. We revisit methodology for collecting peat bulk density data at the FSE site and the use of staff gauges to record the depth of water in canals. New SOPs for these methods were developed, trialed, and implemented, with all 33 staff gauges in the Mawas area replaced.

3.5. Smoke samplings

A team from the University of Montana, IPB University and BOSF monitored *in situ* smoke content using high-tech scientific equipment and collected smoke samples from peat fires near Palangkaraya on October 2015. This unprecedented *in-situ* studies of aerosol and gas emissions from 35 peat fires of varying depths near Palangka Raya, Central Kalimantan, have documented the range and variability of emissions from these major fires. We strongly suggest revisions to previously recommended IPPC's emission factors (EFs) from peat fires, notably: CO2 (-8%), CH4 (-55%), NH3 (-86%), and CO (+39%)[6].

Our findings clearly showed that Indonesian carbon equivalent measurements (100 years) might have been 19% less than what current IPCC emission factors indicate. The results also demonstrate the toxic air quality in the area with HCN, which is almost only emitted by biomass burning, accounting for 0.28% and the carcinogenic compound formaldehyde 0.04% of emissions [6]. The EFs developed herein, combined with estimates of the mass of peat burned, are used to estimate that 3.2–11 Tg of PM2.5 emitted to the atmosphere during the 2015 El Niño peatland fire event in Indonesia. Organic carbon and Elemental Carbon accounted for 2.1 and 0.04% of total carbon emissions, respectively [7].

Recently we did a smoke sampling by using canisters in Riau and Jambi during The 3rd International Workshop and Smoke Sampling Training in August 2019. The canisters will be sent to the US to be analyzed.

3.6. Training and Workshops

Various training and series of workshops have been done to introduce the project and its methodology to related stakeholders, to disseminate the results and findings of the project and to better known an effort made by partners and stakeholders in facing fire problems in their area.

The project held a successful two-day kick-off workshop in Palangkaraya in August 2014 attended by over 50 persons from 26 organizations. The workshop aimed to present the goals and objectives of the research and to highlight some initial results from the monitoring of the fuel, vegetation, and hydrology studies.

In March 2015 and October 2015, the 2nd and 3rd project workshops were held in Kapuas and Palangka Raya respectively. Each workshop attended by approximately 50 participants with representatives from national, provincial, district and village government, including forestry, environment, and disaster agencies, international climate and REDD+ organizations, and provincial and foreign universities. The workshops provided updates on the project by the lead scientists from the US, researchers in the field, and perspectives on the fire situation from guest speakers from the University of Palangka Raya and Kapuas and Central Kalimantan governments.

The internal Kick-Off Workshop for Phase II of the project held in Palangka Raya on 11-12 January 2017. The workshop aimed to introduce the new partners of the project; University of Riau, University of Papua, University of Jambi, University of Palangka Raya and WARSI, and also affiliates of the project; LAPAN, BRG, Indonesia's Ministry of Forestry, to the partners continuing from Phase

I including SDSU, IPB and BOSF, to the work undertaken during Phase I, to the plans for Phase II and to the methodology developed by the project. In total there were 23 participants, from these institutes.

The IPB and BOSF-Mawas teams hosted the UMCES-IPB Peat Fire Research Project Phase II FSE and Peat Fire Behaviour Training Workshop in the Mawas area in Sept 2017, attended by participants from Universities of Jambi, Riau and Papua, WARSI, KPHL-Kapuas, Forestry Office Central Kalimantan, Litbang Banjarbaru and Litbang Palembang.

The 2nd International Workshop on Peat Fire Prevention and FSE Refresher Training held on 23-26 July 2018 in Jambi. The workshop on 23 July 2018 attended by participants from the research team, LAPAN, Forestry Office, Local Government Office, Manggala Agni, and Regional Planning Office. FSE Refresher Training held on 25-26 July 2016 in Desa Danau Lamo, Muaro Jambi Regency, Jambi

The 3rd International Workshop on Peat Fire Prevention and Smoke Sampling Training held on 26-31 August 2019. The workshop on 26 August 2019 attended by participants from the research team, Palangka Raya University, LAPAN, and Manggala Agni. The Smoke Sampling Training is done in Riau (27-28 August) and Jambi (29-30 August).

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