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A proposal of community-based firefighting in peat hydrological unit of Kahayan – Sebangau River: methods and approaches

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A proposal of community-based firefighting in peat hydrological unit of Kahayan – Sebangau River: methods and approaches

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Abstract. In 2019, Indonesia has experienced a very recent El Nino event, which generates an impact on the severity of forest and peatland fires both in Kalimantan and Sumatra. Some provinces such as Central Kalimantan, South Kalimantan, Riau, South Sumatra, and Jambi have been covered in a thick and poisonous haze for months. The total number of fire in Central Kalimantan processed from NASA hotspot data from January to October is reaches 10 000, which approximately 86% occur during two months of the dry season (September – October 2019). The areas that experienced very severe fires in 2019 were Peat Hydrological Unit (PHU) Kahayan – Sebangau River in the administrative boundaries of Pulang Pisau and Palangka Raya. The interesting is the fire in 2019 becomes the four of top fire in Central Kalimantan after 2015, 2006 and 2009. About 10,000 hectares of land including peatlands have been burned only in Central Kalimantan during the forest and land fires season. The smoldering type of peat combustion underground with low-temperature combustion is the most common occurrence in dry peatland areas. This unique fire behavior answers some of the questions why smoldering fires occur over long durations, and why peat fires are difficult to extinguish and produce more smoke. This paper will review the update of 2019's fire in Central Kalimantan and introduce the methods and approaches of firefighting by the local community. The method that will be presented is a combination of scientific data with the experience of the firefighting team, which is called Tim Serbu Api Kelurahan (TSAK). The collaboration project between the University of Palangka Raya, Kyoto University and CIFOR that supported by the Ministry of Agriculture, Forestry and Fishery Japan has proposed to draft a manual for fire prevention and protection for the local fire fighting. This manual covers the method of fire investigation, firefighting preparedness such as making wellbore, fire break, the installation on machine and horse as well as the effective peat rewetting and watering. This method has been tested successfully to slow the movement and spread of fire under thick peat. On the other hand, there is still a need for sophisticated equipment for underground fire detection such as thermal cameras or drones.

1. Introduction

Central Kalimantan has one of the largest tropical peatlands in Indonesia covering an area of about 3 million ha [1]. Over millions of years, this area has accumulated organic carbon and acted as a carbon



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sink. In 1996–97, more than 1 million ha of peat swamp forest (PSF) of Central Kalimantan was drained through drainage channels for conversion to agricultural land under the Mega Rice Project (MRP). The effect was a lowering of groundwater levels (GWL), mainly in the next dry season, causing severe wildfires. Page et al [2] showed that as much as 70% of the PSF was destroyed by fire in 1997. The highest numbers of fires in Indonesia were recorded in the years 2002, 2004, 2006, 2009, 2012, 2014 and 2015 [3], [4]. Forest and land fires in Central Kalimantan did not stop in 2015 under a very strong El Niño event. After these fires, the larger part of PSF was lost and has become abandoned peatland with ferns and grass as the dominant vegetation. The peatland fires produced toxic smoke and they released large amounts of greenhouse gases (CO₂, SO₄, and N₂O). Hooijer et al. [5] estimated that CO₂ emissions from this source in Indonesia averaged 1.42 Gt/y as a lower limit with the possible average maximum of 4.32 Gt/y. Furthermore, biodiversity on peatland and PSF are endangered.

Weather conditions, such as long drought periods, as well as the quantity and quality of fuel are also closely related to the spread of fire. The total accumulation of organic carbon in peatland was reported as being 240 Gt to 480 Gt [6], from the peat and vegetation. In a fire, carbon is a major compound of chemical reactions in the combustion process. The fuel in peat fires is dry peat as well as fresh and/or dead vegetation. Peat and vegetation behave similarly in fires as both are organic matter. When there is little moisture, they are both highly flammable even though flammability charts show different values depending on the wood variety [7] and the degree of peat decomposition [8]. After fires, unburnt peat has the potential to burn again because the depth of the peat layer near Palangka Raya is as deep as 3 meters – or deeper in some cases – and regrowth of surface vegetation provides fuel for repeated peat fires.

The areas of the Peat Hydrological Unit (PHU) of Kahayan–Sebangau River that were converted during the MRP and are not under cultivation now may be subject to uncontrolled and unpredictable forest and land fires. But effective preventive measures are not being taken at present. Limited firefighting facilities and personnel result in frequent and increasingly serious fires, and the study of peat fires is not very active due to complicating factors involving combustion type and smoldering fires. In addition, firefighting efforts handled by the government are not very effective. Indeed, fire behavior and characteristics on peatland are unique, and the environment is fragile compared with other types of land, so fire management methods would differ.

We reviewed previous regulations and guidelines on firefighting in Indonesia. Table 1 shows the strengths and weaknesses of each one. Some of the manuals do not include enough information on community-based firefighting as it is not considered local knowledge in a specific area of PHU. The other problem is that general methods employed in developed countries are not suitable for local use due to the high cost of suppression material. This paper therefore aims to investigate the real experiences of communities and the scientific evidence in order to offer firefighting guidelines that are suitable and applicable to peatland areas. This could be used to upskill local firefighting volunteers for severe fires in Central Kalimantan in the future. Groups that could benefit from the guidelines include Tim Serbu Api Kelurahan (TSAK), Masyarakat Peduli Api (MPA), Barisan Pemadam Kebakaran (BPK) and Barisan Relawan Kebakaran (BALAKAR).

Table 1. The methods and approaches of fire prevention and firefighting in Indonesia before 2019

No	Title	Content	Remark
1	Permanent Procedure for Forest Fire Control for Manggala Agni [9]	<ul style="list-style-type: none"> • Preventive procedures • Fixed blackout procedures • Permanent procedures for post-fire handling and rescue • Permanent procedures for management of fire control HR 	<p>Strength:</p> <p>This document contains a fairly complete procedure for controlling forest fires in Indonesia.</p> <p>Weakness:</p> <p>This document does not contain ways to control</p>

		<ul style="list-style-type: none"> • Permanent procedures for management of facilities and control infrastructure • Control flow chart 	and suppress fires outside forests, especially peatlands.
2	Standard Operation Procedure (SOP) of the Fire Brigade Team [10]	<ul style="list-style-type: none"> • There must be institutional and organized support. • Membership and clear duties • Formation of TSA • TSA member training • There must be a TSA member welfare guarantee, insurance and a permanent income. There must be a technological technique for handling the implementation strategy. • There must be an equipment and operational fund, types of tools and equipment, number of tools, equipment and details of TSA costs, must be multi-functional. 	<p>Strength: This document is based on the experiences of the Central Kalimantan TSA team on the techniques and strategies for combating fires on peatlands. These strategies have been re-tested in forest fires since 2002.</p> <p>Weakness: This document is more focused on firefighting and there are no ways to prevent and handle post-peat fires.</p>
3	Community-based Land Fire Management Training Module [11]	<ul style="list-style-type: none"> • Preliminary • Characteristics of local communities • Institutional control of forest and land fires • Institutional tasks, functions and coordination mechanisms • Information and reporting systems • Institutional work plan 	<p>Strength: This document focuses on the local culture of Central Kalimantan, which has a strong tradition in terms of environmental maintenance and fire prevention.</p> <p>Weakness: This document is still not very practical and requires an SOP for its implementation.</p>
4	Forest and Peatland Fire Guideline [12]	<ul style="list-style-type: none"> • Preliminary • The importance of peatland forest and forest management • Supporting factors for forest and land fires • Forest-fire control policies in Indonesia • Strategic control • Control techniques 	<p>Strength: This document contains the general theory of forest and land fires and their control techniques.</p> <p>Weakness: This document still uses old methods for monitoring and controlling fire and has not paid too much</p>

5	Practice Manual for Managing Forests and Land [13]	<ul style="list-style-type: none"> • General guidelines for managing garden land • General guidelines for managing forest resources • General guidelines for management of forest and land fires 	<p>attention to local wisdom / knowledge.</p> <p>Strength: This document is a guide to managing forests for the prevention of forest fires.</p> <p>Weakness: This document has not focused on fires in peatlands.</p>
6	Land Management Without Burning/PLTB [14]	<ul style="list-style-type: none"> • Definition, distribution and problems of peatlands • Why do you burn land? • Land without burn management is easy • PLTB practice in Kalampangan, Palangka Raya • PLTB practice in Anjir Kalampangan, Kapuas • PLTB practice in West Kanamit, Pulang Pisau • Strengths, weaknesses, opportunities and challenges in implementing land management without burning 	<p>Strength: This document contains real practice methods for managing non-combustible land or PLTB on peat and fire-prone land based on the true story of PLTB actors in several villages of Central Kalimantan.</p> <p>Weakness: This document is still not very practical and requires an SOP reference for its implementation</p>
7	Standard Operating Procedure Concerning Firefighting Techniques Against Peatland and Forest Fires [15]	<ul style="list-style-type: none"> • Basic knowledge about foam fire extinguishers • Soap-based extinguishing ingredients • Fire extinguisher equipment • Basic knowledge of peatland fires • Peat firefighting procedures • Suppression procedure • Attached documents 	<p>Strength: This guideline is a bit more practical compared with the previous one and it is more focused on fire suppression.</p> <p>Weakness: It seems focused on small-scale fires rather than large-scale ones and needs expertise to apply the soap-based fire extinguisher.</p>

2. Methodology

2.1. Study Area

The study was located in the Peat Hydrological Unit (PHU) of Kahayan–Sebangau River around Pulang Pisau and Palangka Raya, Central Kalimantan. It is in the area 2°10' to 3°22' S and 113°38' to 114°14' E (as shown in Fig. 1). Based on Presidential Regulation No. 1 (2016), the restoration target in 2016–2020 is 2 million ha on a PHU basis, one of which is PHU Kahayan–Sebangau River in Pulang Pisau

Regency and Palangka Raya City. Previously this PHU area was known as Block C of the Mega Rice Project (MRP), which was located between the Kahayan and Sebangau rivers. Yulianti et al [16] have shown that the Pulang Pisau Regency is the most fire-prone area in the province, especially under El Niño conditions, with around 50% of the total fires found in Block C of MRP or PHU Kahayan–Sebangau River.



Figure 1. Study Area

2.2. Fire Fighting Observation

Data collection is carried out by observation during the fire season to investigate various types of actual fires on peatlands. Subsequently, records were made of various techniques and approaches undertaken by the fire brigade team or TSAK. The interview with the team is also an important part of confirming the results. Supporting data, such as the number of fire incidents, burnt areas and hotspot distribution, were processed by the Central Kalimantan BPBD Pusdalops (Provincial Disaster Agency). The images of surface peat fire were captured by an infrared thermal imaging camera (Therma Shot F30, Nippon Avionics Co., Ltd., Japan).

3. Weak El Nino's Fire in 2019

3.1. Fire Incidents in Pulang Pisau and Palangka Raya

Figure 1 shows that the fire recorded at the Kahayan–Sebangau PHU was dominated by an incident from Palangka Raya. In August 2019, fires peaked in more than 300 incidents, which was about three times that of Pulang Pisau. Fire incidents in Palangka Raya began to increase after May or about two months earlier than Pulang Pulang. This pattern looks unusual as illustrated in the results of a previous article in Yulianti et al. [17], where the fires were usually concentrated in the Pulang Pisau Regency, particularly in El Niño years. The total of the burned areas (drawn in dashed lines) seems to show a pattern in line with the fire incident, with Palangka Raya the most affected area in 2019. This can be seen from a large number of actual fire areas, as shown in Figures 3 and 4. There are indications that the majority of these fires are located on untapped land or vegetation.

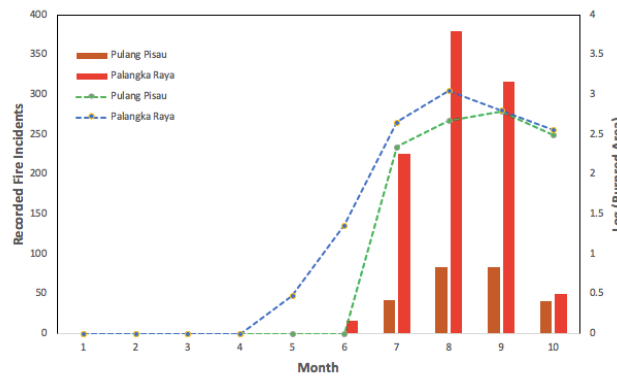


Figure 2. Summary of monthly fire incidences and the burned areas



Figure 3. Actual fire in Bukit Tunggul, Palangka Raya in 17 August 2019



Figure 4. Actual fire in Tumbang Nusa, Pulang Pisau in 7 August 2019

3.2. Smoldering Fire Behavior

The apparent temperature profile of an actual peat fire in the Pulang Pisau area with a thermal camera (Fig. 5) showed that the temperatures in the peat fire zone ranged from 19.9°C to 350°C. The temperature around 347°C was the glowing combustion temperature of peat and coincided with the high heat release observed. The lower temperature was on the frontlines (boundaries), where it was over 120°C, just above the boiling point of water. In this situation, the water content of the peat would generally vaporize, following which the peat layer would start to ignite. This lower temperature boundary may be termed a so-called pre-heating zone [18]. This was a similar situation to that in the center of the burning area, where the temperatures recorded by the Therma Shot were higher than 300°C, but this camera has

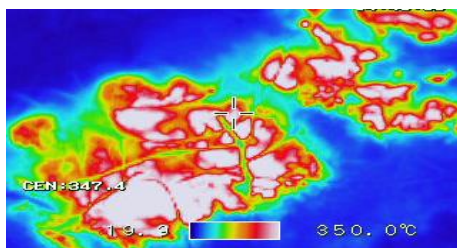


Figure 5. IR image of surface peat fire



Figure 6. PM 2.5 monitoring

limitations for the maximum temperature. In this central zone, where the flaming combustion occurred, there will also be a release of heat and smoke in large amounts.

3.3. Smoke or Haze from peat fire

In addition to producing the intense radiance of heat, peat fires generate smoke and haze during the peak fire season. This atmospheric pollution contains carbon, nitrogen, sulfur and potassium gases, as well as particles of solid and liquid matter, including PM₁₀, PM_{2.5} and ultrafine fractions PM₁ [19]. Visual inspections of the actual fire established that different types of combustion generated different-colored smoke. The flaming vegetation yields black (brown) smoke, and peat smoldering yields dense white smoke (as shown in Figs. 3 and 4). According to experiments by Pryor (1992) [20], radicals of wood smoke generate gaseous combustion products that are more toxic than cigarette smoke and have long lifetimes in air. These radicals can be deposited deep in the lungs of living species that are exposed to this smoke. During the peak fire season, PM_{2.5} concentrations in Palangka Raya, Central Kalimantan, have reached more than 600 µg/m³, or above the Air Pollution Standard Index (see Fig. 6). These values show that the air quality is very unhealthy and hazardous to human life. The dangerous conditions are shown by the respiratory problems that hundreds of people reported and as many as 29 people died [21].

When the smoke from peat fires becomes thick, sunlight hardly reaches the ground surface and then convection is suppressed, potentially leading to stagnation of the smoke. This reduces, or even stops, air circulation and lessens visibility significantly. These conditions are serious for the environment, not just for human health, transportation and communications. During major fires, the massive smoke clouds from the peat fires blanket all of Borneo Island as well as neighboring countries such as Malaysia, Singapore and Brunei. It has caused health problems for residents as well as traffic accidents due to the low visibility, and it lowers agricultural production due to the weak sunlight. Numerous MODIS images clearly showed these conditions, and large white balls of smoke are visible [22]. This situation demonstrates that smoke haze in Central Kalimantan is a major international issue.

4. Methods and approaches of fire fighting in peatland

4.1 Member requirements and the duties

The Center for International Cooperation in the Sustainable Management of Tropical Peatlands (CIMTROP) is a unit of the University of Palangka Raya and was established as a research center based on the Rector's Decree No. 2153 / PT31 / H / I / 1998, dated 9 September 1998. In 2016, this unit entered a new period by forming six research divisions: water (hydrology), biodiversity, agronomy, conservation, restoration as well as fire and emissions. CIMTROP also has 10 to 15 patrol team members who have assisted the TSAK team in Palangka Raya City for the past 20 years.

A TSAK team usually consists of no more than 30 people, depending on the extent of the fire. The number of team members is double what was stated for the MPA in the Indonesian Ministry of Environment and Forestry regulation No. P.32 / MenLHK / Setjen / Kum.1/3/2016 [23]. In the selection of volunteer members for the team, several conditions must be met, including (i) aged from 18 to 50, (ii) physically and mentally fit (not color blind, not deaf, not medicated, etc.), (iii) preferably, members of a local community close to the fire areas, such as farmers, fishermen or hunters, and (iv) must be bound by a work contract that outlines their duties, responsibilities, rights and obligations, and includes sanctions. The requirements for team selection are adopted from the Director General of Forest Protection and Nature Conservation, regulation No. P.4/IV-PKH/2013, which are similar to those for the Mangala Agni team and MPA team [9].

Based on the division of tasks in the field, TSAK members are divided into four sub-teams: TSA-1, TSA-2, TSA-3 and TSA-4. Each TSA sub-team consists of 5–7 people, except for TSA-4 consisting of 5–9 people. The sub-teams are very important to carry out the tasks more efficiently and effectively when the TSA enters the fire location in the forest or the field. This division of sub-teams has never existed or has never been stated in the previous guidelines or regulations [9, 23, 24]. The structure, duties, and responsibilities of members of the sub-team, are as follows:

TSA-1: preparing accomodation and equipment

TSA-2: probing water sources, making wells and installing pumping machines

TSA-3: probing and analyzing hotspots and making transects / firebreaks

TSA-4: operating a pump and fire sprinkling machine

4.2 Tools and Supporting Equipment

To support firefighting activities in the field, several tools and equipment must be prepared, as listed in Table 2. Some of the equipment refers to what is stated in the Ministry of Home Affairs regulation No. 122/2018 [24] and the Director General of Forest Protection and Nature Conservation regulation No. P.4/IV-PKH/2013 [9]. However, in this paper, there are eight categories of equipment needed, two of which are most important for each operation: fire extinguishers and drills. Preparation is vital because the team can stay for days or even months to extinguish peat fires.

Table 2. List of equipment

No.	Category	Tools and equipment
1	Personal needs	Work tools (standard firefighting clothes and shoes, helmets, masks, knives, gloves, drinking water thermos, flashlights / batteries) Sleeping tools (mosquito nets, mattresses, mats) Vacuum glasses Mask Personal equipment
2	Extinguishers	Water pumping machine (HP 4.5 - 6.5) Chainsaw Spiral horse (4 meters per unit with a size of 2 ") Throwing hose (600–1000 m with a size of 1½") Nozzle (size 1½") Branch connection Filter hose spiral or suction hose A set of engine keys Rubber strap (used in inner tube) Engine sparkplug (backup) Hoe Shovel Chopping Knife Tarpaulin
3	Drilling	Water pumping machine (HP 4.5 - 6.5) Pipe type AW 6 rod, size 1 ½ Pipe glue Oil (gasoline, engine oil) Rubber strap (used in motorcycle tires) Spiral hose 3–4 meters with a size of 2" (suction hose) Fabric hose with a size of 1½", depending on the distance of the water source (water supply hose) 6-meter hose with size ¾ " 2 units of the drill bit Ragum (1 piece), hacksaw + hilt Pipe wrench, 2 pieces (size 24") Hoe / shovel, 2 large machetes Gallon / bucket
4	Tent	Tarpaulin Rope Machetes, axes, saws, hammers, nails Carpet Closed plastic Hoe / shovel

No.	Category	Tools and equipment
5	Cookware	Wooden pole
		Mat
		Emergency lamp and lanterns
		Cooking utensils (large saucepan, cage, large / small frying pan, stove)
		Food and drink utensils (plastic / zinc plates, tablespoons / rice / vegetables, plastic cups, bowls and food boxes / plastic bowls).
6	Transportation	Other tools (large / small buckets, plastic water containers, washing container, large / small water gallons, kitchen knives)
		Freight car
7	Communication	Boat
		Motorcycle 125 CC
8	Other	Handy Talky (HT)
		Antenna (RO / vertical / tensile)
		12-volt battery
		cable
		Small fan
		Accu light bulb
		Solar cell (board)
		Binoculars
GPS (Global Positioning System)		
		Stationery
		Storage box
		Stretcher

4.3 Firefighting Methods/Strategy

TSAK–CIMTROP developed methods/strategies that were implemented temporarily to combat severe forest and peatland fires in 1997, 2002, 2006, 2009, 2014, 2015 and 2019. The steps involved in fighting fires in peatland areas are shown in Fig. 7. There are seven compulsory methods and approaches for team members. Some procedures (Steps 1–5) had been applied by previous manuals or guidelines on fire prevention and firefighting in Indonesia before 2019 [9, 10, 11, 12, 13, 14, 15]. The new idea in this latest method is found in Steps 6–7. After first using the fire extinguisher, the team member should check the fire hole one more time using a thermal camera or drone. If there is no heat release and/or potential ignition, it means the fire is completely extinguished. However, if there is any heat release and/or potential ignition, sub-team 4 cannot leave the burning areas. For convenience, each sub-team is equipped with a minimum of one Handy Talky (HT), except for TSA-4 requiring a minimum of two units, namely for the engine supervisor and sprayer at the end of the nozzle. For efficiency, boreholes can be made with machines (Fig. 7) because the hotspots are far enough away. The first machine from the wellbore must deliver water to a container or reservoir, and the second machine draws water from the reservoir. Based on the experience of TSA–CIMTROP in several severe fires during El Niño events, water from bore wells should be sprayed nonstop for 24 hours until there is no fire in the peat layers. This is effective in reducing the ignition process in the underground peat.



Figure 7. The step of fire fighting

No matter how successful the strategy has been, it is highly dependent on the implementer. If good methods and sophisticated equipment are used by people who are less responsible, the approach certainly won't produce satisfactory results. Human capacity is important in fighting fires effectively, particularly in peatlands. This manual or guide has therefore been prepared to upskill the local firefighter who volunteers only during the forest and peatland fire season.

4.4 Mutual Services Ethical

Mutual support is very important. Never allow colleagues working 1–3 km from the camp to run out of water or food, to sustain injuries or to become trapped in a fire. With a sense of solidarity, TSA members who are taking a rest provide drinks, food or medicines, as well as rescue efforts for members who are caught in a fire. Members at work must always be monitored via Handy Talky (HT) radio. If there is no answer at any point in time, the colleague must be checked and contacted directly at the work location.

5. Conclusion

Hundreds of fire incidents in Central Kalimantan in 2019 were spread out in peatland, such as PHU Kahayan–Sebangau River in the administrative area of Palangka Raya and Pulang Pisau Regency. Flameless peat fires are difficult to observe with the naked eye, but they can be detected from heat release on the surface. These fires leave holes that are tens of centimeters deep at the peat fire site. Some methods and approaches have been implemented by TSA–CIMTROP (local firefighter team) to combat forest and peatland fires during El Niño events – particularly in small-scale peatland areas – since 1997, 2002, 2006, 2009, 2014, 2015 and 2019. The evidence suggests that these methods are effective in fighting peat fires but some improvement is needed before the equipment, safety procedures, human capacity.

Acknowledgments

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