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RESEARCH FOR FIRE PREVENTION MANAGEMENT IN INDONESIA (SMOKE, HAZE, GHG EMISSION REDUCTION, AND DEFORESTATION)

(*Penelitian Manajemen Pencegahan Kebakaran di Indonesia (Asap, Kabut Asap, Penurunan Emisi GRK, dan Deforestasi)*)

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ABSTRACT

Forest and land fires, not only in Indonesia but also in other parts of the world, have actually caused tremendous negative impacts. It causes negative impact to the environments (smoke, haze), social, education, health, flora and fauna, state life, and so on that are sourced from most human activities, which have an impact on global climate change. The negative impacts of forest and land fires must be controlled through serious and systematic control of forest and land fires and supported by the political will of the government. It should be understood that forest and land fire control activities should be based on the field facts derived from research results and not based on fictitious results or temporary estimates. Research efforts can also be expected through regional and international cooperation.

Keywords: Forest, fires, research, climate change, collaboration

ABSTRAK

Kebakaran hutan dan lahan, tidak hanya di Indonesia tetapi juga di belahan dunia lain, sebenarnya telah menimbulkan dampak negatif yang luar biasa. Menimbulkan dampak negatif terhadap lingkungan (asap, kabut), sosial, pendidikan, kesehatan, flora dan fauna, kehidupan bernegara, dan sebagainya yang bersumber dari sebagian besar aktivitas manusia, yang berdampak pada perubahan iklim global. Dampak negatif kebakaran hutan dan lahan harus dikendalikan melalui pengendalian kebakaran hutan dan lahan yang serius dan sistematis serta didukung oleh kemauan politik pemerintah. Perlu dipahami bahwa kegiatan pengendalian kebakaran hutan dan lahan harus didasarkan pada fakta lapangan yang diperoleh dari hasil penelitian dan bukan berdasarkan hasil fiktif atau perkiraan sementara. Upaya penelitian juga dapat diharapkan melalui kerjasama regional dan internasional.

Kata kunci: Hutan, kebakaran, penelitian, perubahan iklim, kolaborasi

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INTRODUCTION

The problem of forest fires cannot be considered a simple issue as it involves numerous actors such as local actors, large firms, and political economy actors, such as governors, regents, and regional level companies. Forest fires are not only driven by internal factors like types of peatlands and soils (Purnomo *et al,* 2019). External factors such as the dry climate also contribute to causing forest fires. However, individual behaviors and corporate industry elements were also determined as other major driving factors in forest fires (Özokcu *et al*, 2017). Land burning is also utilized to clear agricultural land areas (for example, to cultivate oil palm) since this technique is relatively inexpensive and simple (Purnomo *et al*, 2020; Ramdani *et al*, 2020). The financial resources of large companies can easily influence local actors to conduct illegal activities for the benefit of companies. Nine of the dozen oil palm groups that had the largest area of burned land in their concessions between 2015 and 2019 did not receive any serious civil or administrative sanctions. The same case can be seen in Brazil, where the local actors are often blamed for starting most forest fires (Cammelli, *et al*, 2019). The lack of government policy can also contribute to forest fire cases such as those in Pakistan, where the lack of government policy has made it easy for companies to clear forests (Zeb *et al*,2019).

Fires in humid tropical forests, both natural and anthropogenic in origin, have been a source of disturbance over millennia (e.g., Goldammer, 1990), but large, intense fires have been relatively infrequent prior to anthropogenic land use change Carbon emissions as a result of fires in peatlands are particularly high, as peat is extremely rich in belowground organic carbon (Cattaua, 2019) ; peat-swamp forest with a depth of 10 m can store 12–19 times the amount of carbon as other tropical forest types (FRIM-UNDP/GEF, 2006). Mean annual CO_2 emissions from decomposition of deforested and drained peatlands and associated fires in Southeast Asia are estimated at _2000 Mt y^{-1} (Hooijer *et al*., 2006). However, there is annual variability in emissions, and emissions during El Niño phases of ENSO far exceed those from non-El Niño periods (van der Werf *et al*., 2008). Over 90% of these peat emissions come from Indonesia, which has the largest amount of tropical peat carbon globally (Page *et al*., 2011; Page *et al*., 2006; Rieley *et al*., 1996).

Fires in Indonesia have consequences from the local to global scale, including burning forest that is home to endemic and endangered flora and fauna, emitting haze that compromises human health and impacts economies across the region, and converting peatlands from a major carbon sink to a major source of CO_2. Identifying the sources of fire ignitions and LULC classes associated with fire ignitions is a key factor for reducing fire on this landscape, as this will allow us to more pointedly target management and policy interventions (Cattaua *et al*., 2016).

INDONESIAN FOREST FIRE

The problem of forest fires cannot be observed merely from a single viewpoint. It must be seen expansively in various contexts. Forest land areas, which are supposedly designated as green zones by the state, are being misused by local actors. Based on the findings, the actors are categorized into three classifications (Purnomo *et al*, 2021). The first actors are key actors who have significant impact in forest fire cases. The second are the contest setters who have a secondary substantial impact in the forest fire cases in Kalimantan. Finally, the subject actors are those who possess the least influence in the forest fire cases in Kalimantan. The key actors are the large oil palm companies, small local plantation companies, and local landowners. In the network, the key actors played an important role in the forest fires cases in Kalimantan. Key actors carried out more activities that devastated the forest by providing resources to contest setters and subject actors (Purnomo *et al*, 2021).

The key actors reaped a lot of benefits from the clearing of new land areas because they could convert them into new productive land areas. In addition, the key actors were impervious to any punishment or fine that may be imposed in a tribunal (Purnomo *et al*, 2021).

The lack of policy that can improve the living conditions of local citizens has compelled the community to seek alternative means to provide for and meet their household needs. Consequently, local actors engage in illegal logging, unsustainable logging, clearing new land, and land conversion. The second actors are contest setters who are permanent employees of companies and oil palm farmers (Purnomo *et al*, 2021). They maintain a relationship with the key actors—large and small companies and landowners. The third actors are subject actors, comprising freelance workers or community members. In this context, high economic pressure causes employees and farmers to take the instant means of clearing the land by using the slash and burn technique. The contest setters and subject actors are victims of an economic trap, which is clearly apparent in the network of local actors in the forest fire cases (Purnomo *et al*, 2021).

The rainforests in Indonesia had always been resistant to fire (Scholte, 2019), even in long dry seasons, because they retained moisture; however, the access roads required for large-scale logging and the felling of tall trees created openings in the canopy, allowing the sun to dry the surface layer of organic matter and leaves, while highly combustible logging waste—stumps, branches, treetops—was strewn everywhere. The inevitable disaster struck in 1982/83 as a result of the El Nino Southern Oscillation (ENSO).

Indonesia frequently appears in international headlines as the site of vast tropical deforestation, and in fact around 30 percent of the national territory has been cleared of trees over the last 65 years (50 percent remains forested). However, since 2002, the Indonesian Government and Ministry of Forestry have been working steadily to curtail deforestation through wide-ranging government regulation, forest management reform, land tenure clarification, and prosecution of companies illegally clearing forests and corrupt officials who enable them (Scholte, 2019).

Ignitions in Indonesia, as in many parts of the tropics, are primarily of anthropogenic origin (Bompard and Guizol, 1999; Bowen *et al*., 2000), resulting in either accidental or deliberate fires. The human contribution to changing fire regimes and our capacity to manage fire remains somewhat uncertain (Bowman *et al*., 2009; Bowman *et al*., 2011). Thus, a key component to understand changing fire regimes in the tropics is to identify the sources of fire ignitions and the land use/land cover (LULC) classes associated with fire ignitions (Cattaua *et al*., 2016).

RESEARCH PRIORITIES

Arguably the most consequential distortions of research priorities in attempts to explain Indonesian forest fires have been the undue attention and the wrong kind of attention accorded to the study of ignition events and their causes. Many studies of the 1997–1998 fires simply did not make the crucial distinction between explanations of the start of fires and explanations of their spread and thus made no attempt to identify and prioritize research needed for the latter in particular (Vayda, 2006).

What then, more precisely, is problematic about the fire research and the fire-management recommendations I am referring to? If what we want to explain and manage are indeed forest fires and not simply ignition events, certain points need to be kept in mind (Vayda, 2006):

1. Not all ignitions lead to forest wildfires, defined here as uncontrolled burning in forest areas.
2. It follows that as far as the objective of preventing or limiting forest damage or destruction from wildfires is concerned, our focus needs to be on forest fires and not ignitions per se as our primary objects of explanation and control.
3. In order to make ignition studies more relevant to explaining and controlling forest fires we need a) studies reconstructing the ignition events that have led to particular forest wildfires, and b) analyses of findings from such studies in order to ascertain whether forest wildfires are more likely to result from ignitions either for some particular purposes or by some particular types of actors.
4. If the possible ignition sources are seen to be many and/or difficult to monitor and control, causal explanation and control of wildfires in tropical moist forests may require priority attention not to ignitions but to changes in fuel loads, decreases in moisture, and similar factors affecting forest flammability, notwithstanding that a convention followed by many fire scientists (e.g., Stolle *et al*., 2003, pp. 278–279; Stolle and Lambin, 2003, p. 376) is to designate these not as causes of forest fires but as “predisposing” factors or conditions.

Accordingly, for the purpose of explaining and controlling the spread of fires in tropical moist forests, it may fairly be said that lower priority should be assigned to studies of all the causes of ignition events or all the ways in which fire is used than to the more specific or sharply focused studies that could provide the kind of needed evidence I have discussed. Among examples I have given are studies reconstructing the paths and ignition sources of particular forest fires; studies of fire use in or near forests during times of drought specifically; fine-grained research on fire behavior and fire susceptibility under varying conditions of fuel availability and moisture; and systematic research on human actions affecting those conditions (Vayda, 2006).

Tropical forests have a vital role in buffering the brunt of global environmental change. The forests act as a giant carbon sink, and well-preserved tropical forests can reduce global emission by at least 30% (Busch & Seymour, 2016; Turetsky *et al*., 2015). Unfortunately, tropical forest conservation efforts have faced a significant challenge from the occurrence of fires (Carmenta, Coudel, & Steward, 2018). Extensive fires have become more frequent and pervasive in tropical forests worldwide (Fernandes *et al*., 2017; Jolly *et al*., 2015). Indonesia has been identified as a hotspot of fires activities, a considerable proportion of which has come from within its peat landscape (Gaveau *et al*., 2015; Ordway, Asner, & Lambin, 2017; Luca Tacconi, 2016; Wijedasa *et al*., 2017). Due to their severity, frequency and cross-scale impacts, Indonesia’s forest and peat fires are of particular concern both nationally and globally.

The forest, in fact, has historically been rich in biodiversity and home to many endangered species, such as orangutans, Sumatran elephants, rhinos and tigers (World Bank, 2016). The 2015 mega-fires produced transboundary toxic haze, and exposure to which resulted in tens of thousands of people in Southeast Asia suffering from acute respiratory ailments (Lin, Wijedasa, & Chisholm, 2017). It is further reported that over 100,000 premature deaths occurred in Indonesia, Malaysia and Singapore (Koplitz *et al*., 2016). The regional economic loss incurred in connection with the fires was ~ 33 billion USD (~ 35 billion USD in today’s money) (Al Jazeera, 2015). Burning forest and peat landscapes emitted ~ 1.5 billion tons of carbon emission – exceeding the annual daily average of carbon emission produced by the U.S. economy for the same period (Van der Werf, 2015; World Bank, 2016).

Furthermore, agribusiness companies, smallholders and small-scale farmers have cleared land by means of fire in often fragmented and degraded landscapes (Carmenta *et al*., 2017). Perceived economic benefits of clearing land through burning (i.e., it is cheap, easy and effective) have driven agribusiness companies and smallholders to use fire as a means for preparing, developing and maintaining agricultural and plantation lands (Purnomo *et al*., 2017; Simorangkir, 2007; Luca Tacconi, 2016). Relatedly, small-scale farmers have cleared land by means of fire – a farming method that is referred to as slash-and-burn – to prepare agricultural land, generate natural nutrients, enhance soil fertility, eliminate destructive weeds and increase production yield (Fox, 2000; Henley, 2011; Kleinman, Pimentel, & Bryant, 1995; Padoch *et al*., 2007). In the same line, environmental activists have advocated for the practice of slashand-burn by small-scale farmers and consider commercial land clearing by means of fire environmentally destructive (Jong, 2017; WWF, 2006). While exuberant use of natural resources, seismic land-use change and land clearing by means of fire within Indonesia's forest and peat landscapes have been responsible for the occurrence of large-scale fires (Cochrane, 2003; Luca Tacconi, 2016; Varkkey, 2013), research shows that stakeholders' actions concerning the fires appear to have perpetuated the fires' recurrence (McCarthy, 2013; Thung, 2018; Trihadmojo *et al*., n.d.; Wijedasa *et al*., 2017).

Analysis made by Trihadmojo (2019) suggests that the emergence of multiple meanings of fire is nested in various elements which categorised in two general types: enabling and immediate. The enabling elements encompass the national political situation, spatial context, and global, regional and national economic situations. The immediate elements consist of the perceived utility of the Indonesian forest, cognitive representations of Indonesia's forest and peat fires, power, interest, ideology and practice. This categorization is derived from the patterns I perceive to link the emergence of diverse meanings of fire among the stakeholders.

Development of large-scale agriculture projects has also led to significant loss of peat swamp forests. For example, in Central Kalimantan, Indonesia, about one million hectares of peat swamp forest was clear-felled and drained for rice production. Unfortunately, the project failed and was abandoned. It not only failed to produce rice, but left behind the degraded peatlands, which until today continue to emit CO_2 related to extensive drainage and annual fires.

FOREST FIRE PREVENTION

Managing Peatlands

Indonesia has over 15 million ha of peatlands, which is over 12% of its forest land spreading across islands of Sumatra, Kalimantan, Sulawesi and Papua. This is the largest tropical peat land in the world, followed by Democratic Republic of Congo, with the peatland area reaches 9 million ha, and the Republic of Congo with the area reaches about 5.5 million ha (Miles *et al*., 2017).

Indonesia does not only work by itself to mitigate problems in relation to peat management and peat fires. We also communicate and collaborate with other countries and international agencies to stop peat degradation and prevent peat fires (MoEF, 2018). In the Southeast Asia Region, as the ASEAN member, Indonesia has ratified the ASEAN Agreement on Transboundary Hazard Pollution (AATHP) through Law No. 26 of 2014 on AATHP Endorsement, dated 14 October 2014. AATHP aims to prevent and control cross-border smoke pollution as a result of land and/or forest fires particularly in peatlands that must be implemented through intensive national, regional and international efforts based on commitment, a spirit of partnership, and a tradition of solidarity to achieve peace, progress and prosperity among ASEAN countries (MoEF, 2018).

The ASEAN Task Force on Peatlands (ATFP) was established to assist monitoring and supporting the implementation of the ASEAN Peatland Management Strategy (APMS 2016-2020). Its main role is to achieve the objectives of the APMS through overseeing the design and implementation of the ASEAN Program on Sustainable Management of Peatland Ecosystems (APSMPE 2014-2020) and other relevant program/projects and facilitating cooperation with relevant partners, and reporting the progress of APMS implementation to COM to AATHP (MoEF, 2018).

An ASEAN cooperation project is the "Measurable Action for HazeFree Southeast Asia" (MAHFSA) funded by the International Fund for Agricultural Development (IFAD) and involves Cambodia, Indonesia, Malaysia, Lao PDR, Philippines, Thailand and Viet Nam. The MAHFSA Initiative will help strengthen existing ASEAN coordinating mechanisms to engage all stakeholders, strengthen capacity, harmonize relevant programs and projects, and facilitate donor agencies to promote fog-free agriculture, sustainable management of peat swamp forests and implementation of ASEAN Haze Roadmap (MoEF, 2018).

Indonesia is also developing modern and advanced techniques in managing peatland and preventing fires. Forestry and Environmental R&D and Innovation Agency (FOERDIA) has provided scientific-based techniques and policies in managing peatlands and preventing fires(MoEF, 2018). In the last 8 years, FOERDIA has been able to provide information related to: (1) Typology and distribution of peatland in Indonesia; (2) Technology to rehabilitate degraded peatland; (3) Phenology of tree species that can adapt to peatland; (4) Alternatives for participatory peatland management; and (5) the impact of deforestation in peatland on GHG emissions. Another institution, Agency for Assessment and Application of Technology (Badan Pengkajian dan Penerapan Teknologi/BPPT) also provides technology for monitoring water table level in peatlands. They provide two technologies for monitoring the main parameter for determining the soundness of peatland. First technology is provided in collaboration with Japanese scientists to monitor water table using Sensory Data Transmission Service, called SESAME. The second technology is called MORPALAGA (Monitoring Real Time Tinggi Permukaan Air Lahan Gambut/Realtime monitoring for peatland water table level) (MoEF, 2018).

Canal Blocking

The most important requirement for the preservation of peat is permanent saturation by water (Page *et al*. 2009, Dommain *et al*. 2010, Evers *et al*. 2017), and to curb peat loss in peatlands affected by drainage it is essential that peat is rewetted and peat hydrology is restored to near-natural conditions. The relationship between groundwater levels and emissions is relatively well understood, and as mentioned earlier Couwenberg *et al*. (2010) found a relationship for converted peatland of 2.45 tC/ha. yr12 per 10 cm of drainage. Simple measures such as raising groundwater tables by operation of tertiary gates can already significantly reduce carbon emissions, and Imanudin and Susanto (2015) found that raising levels in Tanjung Jabung Timur district in Jambi from -47 cm to -23 cm resulted in a halving of emissions, from 11.4 to 5.6 tC/ha yr^{-1}. Furakawa *et al*. (2005) found that carbon loss from lowland rice paddies was one-eighth of that of other crops (cassava, coconut, pineapple), although the Global Warming Potential was almost the same level as that of other crops because of CH4 emissions from these rice paddies. Emissions were found to be lowest in undrained swamp forests. Soil and air temperature play a secondary role in CO2 emissions compared to soil moisture levels, and emissions are clearly largely determined by groundwater levels in peat (Marwanto & Agus, 2013). While it is well known that rewetting of peat reduces peat loss there are few studies in Indonesia.

Drains or canals are an important feature of peatland development. Their main function is to lower the water table so that agricultural activities can be carried out. They may also be used as a transportation mode for logging or plantations. However, drainage of peatlands leads to aeration of the peat material and hence allows oxidation to take place - this process is also called aerobic decomposition (Hooijer *et al*., 2006). This oxidation of dried peat material results in CO2 emissions.

Restoration

Peatland is a storage of huge amount of carbon. It is estimated that peat can contain about 6 tons per hectare of 1 cm depth. Overall, Indonesian peatlands stores about 46 Giga tons, or about 8-14% of the carbon stored in the world peatlands. It is this carbon content that has become source of problems due to its emission when burnt, and at the same time also become a potential solution if well managed, in the context of climate change mitigation and adaptation. In our First National Determined Contribution submitted to the UNFCCC, 17% or over half of the 29% of the emission reduction target, comes from land-based sector, which are mainly forest and peatlands (MoEF, 2018).

The Indonesian NDC has targeted to restore 2 million ha of degraded peatland by 2030 with about 90% success rate. The strategy to restore 2 million ha of degraded peatland can be implemented by restoring 150,000 ha of peatland every year from 2018 until 2030. This strategy may reduce emissions for about 1 GtCO2e within 13 years from now (Muttaqin, Suryandari, Alviya, & Wicaksono, 2017). This is a significant contribution to the achievement of Indonesian NDC. To be able to achieve this target, collaborative actions among parties such as Ministry of Environment and Forestry, Peat Restoration Agency, Research Centres, Universities, Local Governments, Communities and NGOs are a must (MoEF, 2018).

The restoration of degraded peatland has been conducted through (MoEF, 2018):

1. Application of peat restoration techniques that include water management on site level (operational scale);
2. Construction, operation and maintenance works, including the arrangement of canal blocking installation (rewetting infrastructure);
3. Application of cultivation according to local wisdom; and/or
4. Research and development, taking into account and adhering to the development of science and lessons learnt from international perspectives

As the NDC requests for 90% success rate, peatland restoration needs to comply with indicators of success. According to Environment and Forestry Ministerial Regulation No. 16 of 2017 on the Technical Guides for Recovering Peat Ecosystem, the recovery of peat ecosystem function is declared successful when (MoEF, 2018):

1. There is no exposure to pyrite and/or quartz sediments under the peat layer at the point of compliance;
2. Water table level in peatlands are less than 0.4 (zero point four) meters below the surface of peat at the point of compliance;
3. The condition is better than the standard criteria for degraded peat ecosystem as specified in the Environmental Permit;
4. The condition is better than the “degraded standard” of spatial analysis resulted from field survey activities or data analysis and information scale 1: 250,000 (one in two hundred fifty thousand) or the results of monitoring of the point of compliance; and/or
5. The number of plants growing at least in a healthy condition are 500 (five hundred) stems/hectares in the third year.

Ground Water Level

When peatland is drained for forestry and agriculture, an option that can be taken is Land Clearing without Burning (Penyiapan Lahan Tanpa Bakar/PLTB). PLTB is a practice that needs to be done to prevent the use of fire in clearing plant remnants in the area to be planted. Litter or crop residues can be processed into several types of products such as (MoEF, 2018):

1. Compost; plant remnants can be utilized for composting raw materials so that during the growing season farmers can use compost as a natural fertilizer that is environmentally friendly because it can reduce the use or even do not have to use chemical fertilizers.
2. Wood vinegar; making wood vinegar is a PLTB strategy that is relatively new and is still being disseminated to communities. Wood vinegar is useful as a fertilizer as well as compost. Wood vinegar helps restore soil fertility; therefore, farmers can produce it and use it for plating purposes.
3. Charcoal briquettes; the use of waste wood or twigs for the production of charcoal briquettes can also be done so that agricultural waste in the form of wood and twigs are not burned away. Charcoal briquettes can be used as more environmentally friendly fuel for cooking. It is also cheaper. However, there are still obstacles in community-based charcoal briquettes production since the equipment for producing the briquettes is expensive.

The Jokowi Administration have seen that improving forest and land governance may take times. Thus, it needs an acceleration and simultaneous actions to have results in a relatively short period. In terms of fire prevention strategy, the Government of Indonesia then established Peatland Restoration Agency (Badan Restorasi Gambut/BRG) in January 2016, after the big fire incident of 2015. The Agency is tasked to rehabilitate 2 million hectares by 2019, and the current program is to carry out 2.49 million hectares restoration, which include 1.1 million ha to be performed by the Government and partners, while 1.39 million hectares by relevant private companies. This agency focuses on rehabilitating and restoring heavily degraded peatlands in fire-prone areas. Thus, this agency supports the grand strategy for peatland management developed by Directorate of Peatland Degradation Control, Directorate General for Pollutant and Environmental Degradation Control, Ministry of Environment and Forestry (MoEF, 2018).

By the end of 2017, activities in 75 villages had been initiated in six provinces, with a total area of 1,180,446 hectares. These villages are called peat-caring villages, with thousands of its population are considered as guards in the maintenance of peat ecosystems. Revitalization has been undertaken for the livelihoods of 101 community groups (kelompok mayarakat/pokmas) through assisting community to clear lands without burning, developing local commodities, providing training of freshwater fish cultivation, livestock breeding and bee honey production. The area of restored land reaches 1.2 million hectares. This Figure 1 does not include 93 thousand hectares of peatlands restored by partners, and is spread over six provinces (MoEF, 2018).

Observation points of peat water level have been established, that is eight in South Sumatra, seven each in Riau, Jambi, and Central Kalimantan, and one in West Kalimantan. The water level data can be accessed in real time modes. Monitoring the peatland water level

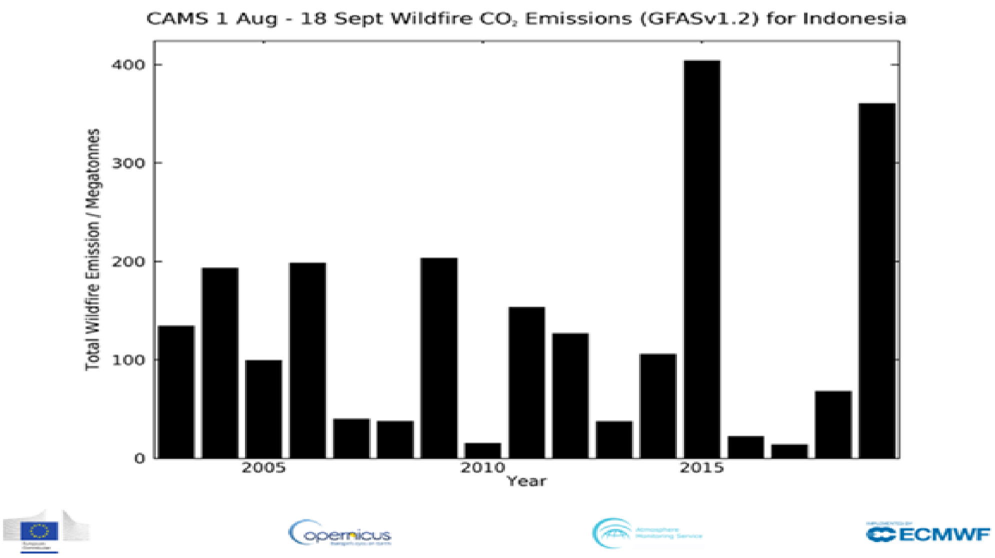

Figure 1 This graph shows the total estimated CO_2 equivalent emissions calculated for Indonesia between 1 August and 18 September for all years between 2003 and 2019. Credit: Copernicus Atmosphere Monitoring Service/ECMWF

is important to identify potential fires and forests. Drained peatlands is a trigger for forest fires that have been a relatively persistent problem for Indonesia. The restoration measures are relatively comprehensive. Not just wetting, trying to restore the peat ecosystem, making the community a vanguard for sustainable peatland management, but also early prevention of fire disasters (MoEF, 2018).

Indonesia has gained extensive knowledge on peatland management through experiences, research and development, and institutional arrangements. In the past, Indonesian people have traditionally utilized peatland for their livelihoods, but some unsustainable managements of peatland have also been experienced by Indonesia during timber boom and agricultural expansion era. These experiences have led Indonesia to focus on the conservation and sustainable management of its peatland (MoEF, 2018).

A comprehensive action has been taken by Indonesian government including formulating policy and regulations, establishing a special agency for peat restoration, and coordinating actions with all levels of government and stakeholders. Policies, regulations, law enforcement and institutional arrangements in improving management of Indonesian peatland have dramatically reduced the degradation of peatland and peat fire events. This also reflects a better governance of Indonesian peatlands that can ensure protection of good peatland areas from degradation and stop degraded peatland from further damage (MoEF, 2018).

To reduce the emission from peat deforestation and degradation through prevention activities is restoration. It could be reached through rewetting, revegetation and revitalization. Rewetting could be implemented well with monitoring ground water level at certain depth which keep the peat surface wet and not resistant to fire.

Groundwater level (>40 cm) can be used as an early warning system for risk of forest and land fire dangers (Silviana *et al*, 2019) because peatland fire occurrent is preceded by low water levels in peatlands. During the dry season, rainfall amounts are lower and GWLs drop, making peatlands very dry and prone to burning. This is especially true during extreme weather conditions and drought during El Niño years (Silviana, 2019, Silviana *et al*, 2020). The highest level of fire risk based on GWL> 40 cm (danger category) is 99.63% in March, making this region very vulnerable to forest fires. GHG fluxes in rewetted organic soils 298 are controlled by a wide range of external and internal factors, which include the prevailing climate, nutrient status, water table position, previous land use history, time since rewetting, absence or presence of vegetation and vegetation composition (Wilson *et al*, 2016).

Jauhiainen *et al*, (2012) said that if groundwater is close to the surface for a long time, then heterotrophic carbon emissions will occur so rapidly along with changes in ground water depth, at this time there will also be a non-linear relationship between groundwater and humidity. Hirano *et al*, (2012) also said that the increase in carbon flow or decomposition of oxidative peat in low groundwater conditions was due to thickening of the unsaturated soil zone and the result of increased aeration

Research conducted by Putra *et al*. (2018) in the ex-MRP showed that most fires in the study area occurred with GWL conditions of 30 to 39 cm below the peat surface, but that fire occurrences with GWL of less than 10 cm below peat surface indicate that degraded peatlands are very vulnerable to fires even under relatively moist conditions. Therefore, degraded peatlands should be maintained in wet conditions with critical GWL of less than 5 cm to prevent surface peat fires from occurring.

Research by Hirano *et al*, (2012) suggests that the relationship of groundwater and carbon flow is a linear relationship. Jauhiainen *et al*, (2012) also said, when measuring the relationship between CO2 emissions and the depth of groundwater, it must be remembered that the depth of groundwater does not control the oxidation of peat. Conversely, it is used to measure moisture from peatland above groundwater, which has a direct effect on peat oxidation by affecting the availability of oxygen in porous space. Also added that on peatlands which have high groundwater depth and no good drainage control, had a strong relationship with soil moisture (Darung *et al*, 2019). Effect of distance from canal main on CO2 emissions does not significantly affect changes in CO2 emissions in the blocks of oil palm plant age (3, 4, 5 and 913 6) years after planting, but the farther away from canal main CO2 emissions are increasing (Darung *et al*, 2019).

Table 1 Burned peatland (ha) at the PRA restoration area (MoEF, 2019)

Province	**2018**	**2019**	**%**
South Sumatera	2,071	133,711	6,460
Central Kalimantan	27,516	175,915	640
West Kalimantan	39,573	59,729	150
South Kalimantan	9,902	11,305	114
Riau	33,867	62,965	186
Jambi	622	24,045	3,870
Papua	2,372	2,199	-7,3
PRA Restoration area	**115,923**	**469,869**	**405**
Burned peatland area in PRA	**125,340**	**480,178**	**383**

Community Based Fire Management

The choice of strategy in suppressing wildfires and carrying out prescribed burning depends largely on how the fire is expected to behave i.e., its rate of the spread, direction of travel and intensity (Saharjo, 2006). The aspects of fire behavior which are prerequisites for the start and spread of fire are flammable fuels, sufficient heat energy to bring fuels to the ignition temperature and adequate of oxygen (Lorimer 1990). How and why fire behave is determined by a number of inter related factors such as fuel, weather, topography and seasonal changes and tome of day (Lorimer 1990).

Results of research shown there was a tendency that low level of peat decomposition (fibric) will have lower rate of the spread of fire, higher flame height that directly related to fire intensity which finally resulted in less peat destroyed (Saharjo, 2006). This means that fire in the low level of peat decomposition was relatively difficult to be controlled. Among the three site Sapric, hemic, and fibric that burned, it had been found that fire in fibric site will be the most difficult to be controlled when fire blow up and sapric site will be the worst (Saharjo, 2006).

A study carried out in Pelalawan, Indragiri Hulu and Indragiri Hilir, Riau Province by Rohadi (2017) revealed that it is difficult for the farmers to follow the Government's zero-burning policy on peatland. As a result, a number of landowners decided to leave their farms as their harvest could not compensate the high production cost for land preparation (Murniati and Suharti, 2018). In this situation, the abandoned lands create a higher risk of wild fires during the dry season due to the build-up of biomass from the bush. To resolve the problem, Rohadi (2017) suggested that there should be a flexible approach in the implementation of zero-burning policy on peatland so as not to harm small farmers in the long run. Genuine farmers should be allowed to implement controlled land burning. Traditional community wisdom makes it possible to apply the technique with the guidance of government officials in the field. Furthermore, as compensation from the farmers' efforts in applying zero burning in land preparation, adequate incentives should be provided (Murniati and Suharti, 2018).

Furthermore, incentive scheme for zero burning practice should be in the form of beneficial programs enabling farmers to prepare unburn farming (Murniati and Suharti, 2018). This is in accordance with several complains revealed by farmers (especially middle-low farmers) who have difficulties in processing their peatland without burning. They need technical guidance and assistance as well as provision of equipment and production facilities. The program should be implemented gradually, starting with the preparation or precondition of the community (peatland farmers) through socialization and raising awareness of the community to prepare land without burning. Further training and technical guidance, supply of peatland processing equipment, subsidized production facilities, especially agricultural lime (dolomite) and NPK fertilizer should be provided for the community (Murniati and Suharti, 2018).

GHG EMISSION REDUCTIONS

Nevertheless, the evaluation of GHG emissions remains high uncertainties in tropical peatland. The environmental factors controlling GHG fluxes vary spatially due to land use (Takakai *et al*, 2006, Couwenberg *et al*, 2010)), microtopography of peat surface (Lampela *et al*, 2014)), and location in a peat dome (Sangok *et al*, 2017). Thus, the high uncertainties of GHG emissions might be due to large spatial heterogeneity. However, studies on spatial variations and spatial controlling factors of GHG fluxes are still limited in tropical peatland and have not been understood well.

Because the mitigation strategies to reduce each GHG emission are different, it is necessary to quantify how much each GHG contributes to the whole global warming potential (GWP) so that the most important factor is revealed to reduce the whole GWP. However, studies on the contribution of each GHG to GWP are still limited (Jauhiainen *et al*, 2012). In Southeast Asian tropical peatland, land use types have drastically changed since 1990s driven by land reclamation (Miettinen *et al*, 2011), drainage (Hirano *et al*, 2011, Hooijer *et al*, 2012), and peat fires (Yulianti *et al*, 2012). These events have led to the patchy distribution of land use types. The land use types have influenced the environmental factors controlling GHG fluxes, and thus GHG fluxes (Takakai *et al*, 2006, Couwenberg *et al*, 2010), Inubushi *et al*, 1998). Therefore, the contribution of each GHG might be changed in different land use types.

Using global palm oil prices, and a geo-specific palm oil suitability measure, Macdonald and Toth (2008) establish a causal link between global palm oil demand as proxied by prices, and fires. A simple simulation exercise based on our linear model shows that for the average district, an increase in palm oil prices of 10 percent in the lead up to fire season will lead to a 12.9 percent increase in monthly fire activity. We show that palm oil prices contribute positively to fire activity across annual and six-monthly lags leading into the fire season (Macdonald and Toth, 2008). This analysis suggests the possibility of developing a quantitative tool to rapidly predict fires across space and time. More generally, we have shown that demand-side factors have significant implications for fire activity, while failing to find a similar link for Indonesia’s second fastest growing crop by land area, rubber (Macdonald and Toth, 2008). More broadly these results highlight two key factors that contribute to differences in fires across districts and years. Rainfall, and hence the cycles of El Nino and La Nina, are also a major contributing factor to annual fire activity, as is the level of forest cover.

Macdonald and Toth (2008) paper also show that land more suitable to palm is more likely to be burnt. The results suggest that improved governance has a key role to play in fire prevention, and the Indonesian government must promote sustainable methods for conversion to palm oil as they seek to meet their palm oil production objectives (Macdonald and Toth, 2008). This study has important implications for the design of policies intended to reduce the prevalence of fires. The central government of Indonesia aims to double palm oil production between 2015 and 2020, so it is important to consider the impact palm oil may be having on fires (Edwards and Heiduk, 2015). Our analysis provides evidence on a couple of key channels behind the fires, and shows that they play a significant overall role in causing deforestation in Indonesia. In particular, the results suggest that in order to reduce fires, the government should pay particular attention to governance capacity in identifying, monitoring and enforcing anti-burning laws (Macdonald and Toth, 2008). Our analysis also suggests the possibility of constructing a predictive model to forecast fire activity across Indonesia to coordinate fire prevention activities, combining indicators that are cheap, and publicly-available with minimal time lag, such as global palm oil prices, rainfall, and measures of suitability for palm oil conversion. Such a model could be augmented with richer data, such as on local palm oil prices. This raises the potential of developing methods to target prevention and enforcement activities where new fires are most likely to occur (Macdonald and Toth, 2008).

One of the reasons that the ambitious efforts of Indonesia's Ministry of Environment and Forestry and other government agencies to implement sustainable forest management do not garner the international recognition or support they deserve is that rapid technological developments in forest and carbon stock monitoring in the last decade (entailing varying definitions of what constitutes a forest) have produced wildly different estimates of deforestation and emissions, as well as considerable confusion and controversy about which figures are correct. The Indonesian Ministry of Environment and Forestry recently protested the reputational damage caused by the widespread dissemination of data that paints its deforestation situation in much bleaker terms than it believes warranted (Scholte, 2019).

Tropical forest protection was thus reborn as a climate mitigation strategy. In December 2007, forests were incorporated into climate negotiations at the United Nations Climate Conference of the Parties (COP 13) to the 1992 UN Framework Convention on Climate Change (UNFCCC) in Bali, Indonesia. Negotiations eventually led to agreement in Warsaw in 2013 on the REDD+ framework for results-based payments for reducing forest-based emissions, which was endorsed in the 2015 Paris Agreement. Development cooperation agencies returned to the forestry sector, and a new generation of forestry conservation initiatives was launched (Scholte, 2019).

The Indonesian Government has not been telling lies; in fact, trained technicians at the Ministry of Environment and Forestry (MoEF), supported by international (including GIZ) experts, produce annual land cover maps derived from the visual interpretation of medium resolution Landsat satellite images and high-resolution SPOT satellite images. The results are validated with ground truthing where there are uncertainties (Scholte, 2019).

The MoEF has therefore recently protested the reputational damage caused by the widespread dissemination of Global Forest Watch data. The MoEF not only produces increasingly accurate land cover maps; in the last 17 years, it has also made significant progress towards forest management reform, land tenure clarification, and precise government regulations. It is working to station well-trained forestry officials on the ground to continually monitor the forests, enforce the laws, and implement sustainable forest management. And it is taking legal action against illegal logging (Scholte, 2019).

Rewetting of drained tropical peatlands will potentially lead to large mitigations of carbon dioxide emissions. Quantifying the rise in groundwater levels of hydrological restoration projects in peatlands together with an estimation of the mitigation in CO2 emissions caused by this rise, is important information to make greenhouse gas emission mitigations tradable under the voluntary carbon market or REDD (Reducing Emissions from Deforestation and Degradation) mechanism. After construction of all dams, hydrological modelling indicates a rise of annual average groundwater levels of 20 cm. With a reported emission mitigation of approximately 0.8–0.9 t CO2 $ha^{-1}a^{-1}$ per centimeter groundwater level rise (Jaenicke *et al*. 2010).

Drained peatlands are highly susceptible and frequently subjected to fire, resulting in significant greenhouse gas emissions (Field *et al*., 2016) and transboundary haze pollution that cause extremely severe human health problems (Kunii *et al*., 2002; Marlier *et al*., 2013), economic losses (World Bank, 2016) and international tension throughout the region. Fires are started for the purposes of land clearing and claiming, fishing, hunting, cooking and non-timber forest product collection (Sinclair *et al*., 2020). However, in drained, degraded landscapes, these surface fires are often difficult to control or properly extinguish, and can escalate into wildfires and persistent smoldering peat fires. Drainage also stimulates biological oxidation of peat in the upper peat profile, and the resultant greenhouse gas emissions are equal to if not greater than those from fire (Hooijer *et al*., 2014; Miettinen *et al*., 2017).

The amount of CO2 emissions resulting from drainage is very much dependent on the ground water level, i.e., the lower the water table, more CO2 will be emitted to the atmosphere. Figure 9 below shows the relationship between CO2 emissions and water table depth. This linear relationship implies that for every 10 cm of water drawn down from the water table there will be an increase in CO2 emissions of 9.1 t CO2 /hectare/year (Hooijer *et al*., 2010)

CONCLUSION

Forest fires problems should be solved through scientific based and field experiment in order to get the clear understanding and reduce the bias. To solve the problems, emerge in the fields, research collaboration is one of the problems as it can be as an answer not only in the site but also in other side with modification. As long as there is possibility to have working together, then working together is one of the best solutions for regional problems on forest fires.

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