Bridging the Services of the WMO Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System (VFSP-WAS) to Politics, Policies and Land Management: the South East Asia Example and Global Visions

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ABSTRACT – The use of fire in land management and land-use change and wildfires affecting forests and peatlands in South East Asia constitute a major threat to the environment and society. Fire applied in land-use change contributes to a net increase of radiatively active trace gases (greenhouse gases) in the atmosphere, thus constituting a major anthropogenic contribution to microclimate change. Close-to-ground air pollution results in serious threats to human health and security. In addition, land-use fires and wildfires affect fire sensitive ecosystems such as equatorial tropical rainforests and peatland biomes where they have detrimental impacts on ecosystem processes, biodiversity and livelihood of indigenous populations. Sustainable management of these ecosystems, which are vulnerable to excessive modification by humans and to fire must be based on the field experienced, because single factor management could not work alone as Indonesia is looking for the permanent solutions. The Regional Fire Management Resource Center – South East Asia/RFMRC-SEA provides the bridge from the services of the planned WMO Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System/VFSP-WAS to the development of sustainable land and fire management policies and management practices.

Keywords: Peat fire; Indonesia; policy; greenhouse gases; Regional Fire Management Resource Center-Southeast Asia.

Integrando os Serviços do Sistema de Consulta e Alerta de Poluição Causada pela Fumaça Decorrente do Fogo na Vegetação da Organização Meteorológica Mundial (VFSP-WAS-WMO) nas Políticas Públicas e Estratégias de Gestão Territorial: o Exemplo do Sudeste Asiático e Visões Globais

RESUMO – O fogo como ferramenta no uso e na mudança do uso da terra, e os incêndios florestais que afetam as áreas de floresta e de turfa no sudeste asiático constituem uma grande ameaça ao meio ambiente e à sociedade. O fogo utilizado na mudança do uso da terra contribui para um aumento líquido de gases traço ativos radioativamente (gases de efeito estufa) na atmosfera, constituindo assim uma importante contribuição antropogênica para a mudança do microclima. A poluição do ar próxima ao solo resulta em sérias ameaças à saúde e segurança humanas. Além disso, a aplicação do fogo no uso da terra e os incêndios florestais afetam ecossistemas sensíveis ao fogo, como florestas tropicais equatoriais e turfeiras, onde têm impactos prejudiciais sobre os processos do ecossistema, a biodiversidade e a subsistência das populações indígenas. Considerando que a Indonésia está buscando soluções permanentes, o manejo sustentável desses ecossistemas, que são vulneráveis às excessivas modificações antropogênicas e ao fogo, deve basear-se na experiência de campo, uma vez que o manejo de um fator único poderia não funcionar sozinho. O *Regional Fire Management Resource Center – South East Asia/RFMRC-SEA* estabelece a conexão entre os serviços do *WMO Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System/VFSP-WAS* para o desenvolvimento de políticas públicas sustentáveis de manejo do solo, manejo do fogo e práticas de gestão.

Palavras-chave: Fogo de turfa; Indonésia; políticas públicas; gases de efeito estufa; Fire Management Resource Center-Southeast Asia.

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Integrando los Servicios del Sistema de Consulta y Alerta de Contaminación por Incendios de Vegetación y Humo de la Organización Meteorológica Mundial (VFSP-WAS-WMO) en las Políticas Públicas y Estrategias de Gestión Territorial: el Ejemplo del Sureste Asiático y Enfoques Globales

RESUMEN – El fuego como herramienta para el uso de la tierra y el cambio de uso de la tierra, así como los incendios forestales que afectan las áreas de bosques y turberas en el sudeste asiático representan una gran amenaza para el medio ambiente y la sociedad. El fuego aplicado en el cambio de uso de la tierra contribuye a un aumento neto de gases traza radiactivamente activos (gases de efecto invernadero) en la atmósfera, lo que constituye una importante contribución antropogénica al cambio del microclima. La contaminación del aire cerca del suelo resulta en serias amenazas para la salud y la seguridad humanas. Además de eso, el fuego como herramienta para el uso de la tierra y los incendios forestales afectan los ecosistemas sensibles al fuego, como los bosques tropicales ecuatoriales y las turberas, donde tienen impactos perjudiciales en los procesos de los ecosistemas, la biodiversidad y los medios de vida de las poblaciones indígenas. Teniendo en cuenta que Indonesia está buscando soluciones permanentes, el manejo sostenible de estos ecosistemas, que son vulnerables a cambios antropogénicos excesivos y al fuego, debe basarse en la experiencia de campo, ya que la gestión de un solo factor podría no funcionar por sí sola. El *Regional Fire Management Resource Center – South East Asia/RFMRC-SEA* establece el puente entre los servicios del *WMO Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System/VFSP-WAS* para el desarrollo de políticas públicas sostenibles de manejo de la tierra, manejo del fuego y prácticas de gestión.

Palabras clave: Fuego de turba; Indonesia; políticas públicas; gases de efecto invernadero; Fire Management Resource Center-Southeast Asia.

Introduction

Transboundary haze pollution due to the smoke from using fire in land preparation has continued to be a big problem in Indonesia every year, especially during the dry season. It has been found that most of the smoke originates from illegal use of fire in converting native vegetation – forests and peatlands – to oil palm and industrial forest plantations (60%-80% of all fires). The traditional use of fire in shifting cultivation, which constitutes a minor share of all burning activities, is usually blamed for the smoke pollution (Saharjo, 2017). Planned and unplanned peat fires are the main source of local and regional smoke pollution.

Fires in Indonesia have consequences from local to regional scale, including burning forest that is home to endemic and endangered flora and fauna, emitting smoke 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 Land Use and Land Cover/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).

Ignitions in Indonesia, as in many parts of the tropics, are primarily of anthropogenic origin (Bompard & Guizol, 1999; Bowen *et al*., 2000), resulting from 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, 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).

In 2015, forest and land fires burned about 2.6 million ha in Indonesia and released about 1.74 Gt CO_2e. Under the Business as Usual/BAU scenario, these emissions were roughly 60% of the 2030 target (2.88 Gt CO_2e) of Indonesia's Intended Nationally Determined Contribution (INDC). Fire prevention activities have, therefore, become critical for Indonesia to achieve its 29% GHG emissions reduction goal by 2030 (NPA *et al*., 2017).

The strategic choices for suppressing wildfires and carrying out prescribed burning largely depend on how fires are expected to behave, *i.e.* rates of the spread, direction of travel, intensity and severity (Saharjo, 2016). The aspects of fire behaviour that are pre-requisites for the start and spread of fire are flammable fuels, sufficient heat energy to bring fuels to the ignition temperature and adequate oxygen concentrations (Lorimer, 1990). Fire behavor is determined by a number of interacting factors such as fuels, weather, topography as well as seasonal changes, time of day (Lorimer, 1990) and vegetation (Silviana *et al*., 2019a).

Fire suppression efforts, lost timber and crop resources, missed workdays, and travel disruptions incur high economic costs (Tacconi, 2003; Ruitenbeek, 1999). It is estimated that Indonesia lost US$20.1 billion during the 1997/98 fire season alone (Varma, 2003). Prior to 2015, both national and international policies have been implemented in attempts to reduce fire in Indonesia prior to the 2015 (*e.g.*, ASEAN Agreement on Transboundary Haze Pollution, Singapore's Transboundary Haze Pollution Act, and Indonesia's national law [Act n. 41/1999]) banning corporations from using fire to clear land for palm-oil plantations), but with limited success (Cattaua *et al*., 2016). Given the variety and severity of the consequences from tropical peatland fires, particularly those in Indonesia, it is of global interest to understand this changing disturbance regime and reduce fire occurrence (Harrison *et al*., 2009).

Forest and land fire significantly affect the quantity and quality of natural resources and ecosystems by reducing the diversity of flora and fauna, decreasing soil quality, changing hydrological functions and contributing to climate change (Goldammer 1991, 1993, 1999, 2006; Goldammer & Seibert, 1990). A further dimension is the sensitive political aspects of transboundary smoke pollution from fires which not only disrupt the Indonesian environment but also conditions in neighbouring countries (Saharjo, 2016; Wasis, 2018).

Forest fires and peatland fires

Who is responsible for fire ignitions in Indonesia is highly contested, and reports of ignition sources are many and varied (Dennis *et al*., 2005; Page *et al*., 2013), often resulting in a chain of finger pointing. Although some large holders clear land mechanically, most land in Indonesia is cleared using fire (Stolle *et al*., 2003). Because fires set for clearing can 'escape' beyond their intended boundaries, both large and small holders have been held responsible (Stolle *et al*., 2003; Page *et al*., 2006, 2013), as is often the case in rainforest fires more generally (Goldammer, 1991). Burning to clear land has been the traditional practice of smallholders and indigenous groups, and there is some evidence that smallholders' use of fire has historically been relatively small-scale and well-managed (Tomich *et al*., 1998; Bowen *et al*., 2000).

However, this is likely not the case today. The scale of land clearing using fire has expanded substantially, with increased use of burning by both smallholders and larger-scale rubber and oil palm concessions (Brauer & Hisham-Hashim, 1998; Potter & Lee, 1998; Stolle *et al*., 2003). Originally, the Indonesian government blamed smallholder shifting cultivators for widespread fires, but later publically claimed that it was more likely larger-scale companies opening land on commercial plantations for palm oil, pulpwood, and timber, some of which was promoted by government policies themselves (Brown, 1998; Page *et al*., 2013).

Drainage of peatlands has resulted in very dry conditions when rainfall is lacking (*e.g.* dry seasons and droughts) that enable fire to burn across these carbon-rich wetlands. These fires can cause irreversible hydrophobic changes to exposed peat soils that eliminates the peat's ability to store and absorb water (Ritzema, 2007).

Drained peatlands are highly susceptible and frequently subjected to fire, resulting in greenhouse gas emissions (Field *et al*., 2016) and transboundary haze pollution that cause 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 smouldering 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).

Fire is also used as an agricultural tool to clear vegetation (Carlson *et al*., 2012; Page *et al*., 2002, 2006). These human disturbances can make peatlands particularly prone to fire. In 2015, 53% of fires in Indonesia occurred on peatland, which made up only 12% of the land area (Miettinen *et al*., 2017).

Burn depth depends on the level of the water table and the water content of the peat, with increased burn depth when the water table is lowered and the peat dries out (Ballhorn *et al.*, 2009; Rein *et al.*, 2000). Konecny *et al.* (2016) also suggest that burn depth changes based on the frequency of fire, with reduced burn depth for repeat fires at the same location. Information on the spatial and temporal variability of burn depth is limited and current emission inventories make broad assumptions regarding these parameters (Kiely *et al.*, 2019).

The different fuel characteristics (size, moisture, bed depth and type) of various levels of peat decomposition (fibric, hemic, sapric) significantly affect fire behavior and the depth of peat destructionResearch has shown that peat with low levels of decomposition (fibric) experiences lower fire spread rates, higher flame heights, and related fire intensity, but less total peat destroyedHigh fire intensities make these fires relatively difficult to control. Among the three peat decomposition types (sapric, hemic, and fibric) that burn, flaming fires in fibric peat is the most difficult to control but smoldering burns in sapric peat will be the most severe (Saharjo, 2006).

When peat forests are disturbed, the peat typically begins to subside (KFCP, 2014). The subsidence rate is correlated, to some extent, with drainage depth (depth of the water table) across a wide range of environmental conditions, suggesting that it may be a useful proxy for the rate of peat decomposition. However, a range of other factors such as vegetation cover and prior fire disturbance also affect subsidence, although their effects are difficult to quantify. Couwenberg *et al.* (2009), in their survey of the literature, found a linear relationship between subsidence rate and water depth for Southeast Asian tropical peat soils, with subsidence increasing by ~0.9cm yr-1 for each 10cm of additional drainage depth. This is substantially more than in other parts of the world (Hooijer *et al.*, 2006; Couwenberg *et al.*, 2009).

Peat destruction due to heat penetration depends on how much fuel is present and peat characteristics, especially moisture content (Saharjo & Munoz, 2005). Peat destruction was prevented through high peat moisture content resulting from the water from the canal surrounding the burn area. Another important factor is the drying process, which determines smoke production during burning and the time needed for burning available fuels. In order to let the fire spread naturally and minimize peat destruction, it is recommended to leave only small diameter (< 5cm) branches for burning and to make sure that materials are dried to no more than 10% moisture content. Without these changes, it is difficult to say that land preparation can be done with less impact (Saharjo & Munoz, 2005).

Peat fire emissions

GHG emissions from fires that burn above-ground fuels are reasonably well understood, but are very different in character to peat fires that are very poorly understood (KFCP, 2014). Smouldering peat fires produce more CO relative to CO_2, and there can be significant loss of C as other volatile compounds. In an excellent study in which the smouldering of blocks of peat was realistically achieved under a range of moisture contents, Rein *et al.* (2009) found that only 60% of the C in combusted peat was emitted as $CO+CO_2$ (*i.e.* there were emissions of many other volatile C compounds). This contrasts with about 95% of combusted C released as CO_2+CO for surface fires.

Peat fires in Southeast Asia, and Indonesia in particular, are consequently a major cause of smog and particulate air pollution (Hayasaka *et al.*, 2014; Reddington *et al.*, 2014), with consequences for human health (Schwela *et al.*, 1999, Goh *et al.*, 1999; Kunii *et al.*, 2002; Marlier *et al.*, 2013; Wooster *et al.*, 2012) and local blocking of sunlight that can suppress plant photosynthesis (Davies & Unam, 1999). In addition, peatland fires are responsible for forest habitat loss and degradation of flora and fauna, including those in marine systems (Jaafar & Loh, 2014; Posa *et al.*, 2011; Yule, 2010).

Page *et al.* (2002) reported that during four months (July – October), the 1997 peat fire in Indonesia emitted about 0.81 to 2.57 gigatons (Gt) carbon to the atmosphere which was higher than that calculated for the 2015 peat fires (Harris *et al.*, 2015). The reasons for this discrepancy was that the 1997 peat fire burned much larger area of peatlands (about 6.8 million ha), and the same emission factors were used for Sumatra, Kalimantan and Papua peat fires.

In 2015, the increase in emissions above baseline was mainly due to large amounts of

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emissions from peat fires during droughts caused by the El Niño event that resulted in huge fires throughout the country (Sugardiman, 2018). The total area of peatlands affected by fire was 869,754ha, with emissions of about 549.4 million t CO_2e. Deforestation also increased above the baseline rate, *i.e.* up to 1.09 million ha. In 2016, implementation of fire prevention programmes and efforts to avoid deforestation helped to reduce emissions, with only 97,787ha of peat fires and just 0.63 million ha of deforestation (Sugardiman, 2018). Overall, this sector was able to reduce emissions by approximately 132.256 million t CO_2e in 2016.

Indonesia contains large areas of peatland that have been drained and cleared of natural vegetation, making them susceptible to burning (Kiely *et al*., 2019). Peat fires emit considerable amounts of carbon dioxide, particulate matter (PM) and other trace gases, contributing to microclimate change and causing regional air pollution. However, emissions from peat fires are uncertain, due to uncertainties in emission factors and fuel consumption (Kiely *et al*., 2019).

Peat characteristics vary greatly spatially due to differences in vegetation and variation in environmental factors that affect peat formation. Stocks of C and N in peat, by depth, represent the starting point for estimating GHG emissions following disturbance (e.g. drainage, or combustion by fire). There is a critical need for a better, finer-scale mapping of peat C and N stocks by depth to which the areas and nature of disturbance (*e.g.* depth of drainage, depth of peat burned in fire) can be linked (KFCP, 2014).

The depth of peat burn is a crucial factor controlling emissions from peat fires but it is poorly constrained. Using satellite remotely sensed surface soil moistures to control the assumed depth of peat burn improves simulations of particulate matter (PM) emissions. However, there is little data available on the relationship between surface soil moisture and burn depth, more work on this could lead to further simulation improvement. Work is also needed to examine whether this is consistent for years other than 2015 (Kiely *et al*., 2019).

The same authors estimated that peat burning contributed 71% of total primary PM 2.5 emissions from fires in Indonesia during September–October 2015. Using satellite-retrieved surface soil moisture to modify the assumed depth of peat burn improved the correlation between simulated and observed PM emissions from 0.48 to 0.56. Overall, it is suggested that peat fires in Indonesia produce substantially higher PM emissions than estimated in current emission inventories. Indonesia contains 36% of the world's tropical peatland (Kiely *et al*., 2019), the largest of any country in the tropics (Dargie *et al*., 2017; Page *et al*., 2013). Undisturbed peatlands typically have high moisture content, making them naturally resilient to fire (Wösten *et al*., 2008). Indonesian peatlands are experiencing deforestation and conversion to agriculture, oil palm and timber plantations (Hansen *et al*., 2013; Gaveau *et al*., 2014; Miettinen *et al*., 2017). During this conversion, drainage canals are installed, lowering the water table and making the peatland more susceptible to burning (Konecny *et al*., 2016).

Fires on peatland can burn into these underground organic layers and smoulder for weeks after surface fires have gone out (Roulston *et al*., 2018), resulting in substantially greater emissions compared to surface vegetation fires (Heil *et al*., 2006). Peat fires are estimated to contribute 3.7% of global fire carbon emissions (van der Werf *et al*., 2017). In Indonesia, peatland fires are the largest contributor to fire emissions in the region (Reddington *et al*., 2014; van der Werf *et al*., 2010). For the 2015 fires, Wooster et al. (2018) found that 95% of the particulate matter (PM2.5) emissions came from peatland fires.

Kiely *et al*. (2019) found that emissions from peat combustion make up a substantial fraction of total fire emissions from the region. Estimated peat combustion contributed 55% of total CO_2 emissions and 71% of primary PM2.5 emissions during September–October 2015. Peat combustion contributed 76% of fire-derived surface PM2.5 concentrations over Sumatra and Borneo during this period. This highlights the importance of peat fires and the need for better estimates of emissions from peat combustion.

Peat restoration as part of the solution

During 2014, in order to save peatlands from destruction and increase future productivity, the government launched Government Regulation n.71, which provides important tools for protecting peat from fire. Regulation n.71 states that the ground water level (GWL) of 0.40m below the peat surface is a critical point that should not be exceeded. This groundwater threshold level was based on scientific evidence of more than 30 years of dedicated research.

Usup *et al*. (2004), Wösten *et al*. (2008) and Putra & Hayaska (2011) have suggested the critical ground water level of 40cm below peat surface should not be breached in order to prevent destructive peat fires. However, field findings suggest that shallower GWL below peat surface should be maintained to prevent peat fire occurrences in dry-degraded peatlands (Putra *et al*., 2016). Fires were found to occur during GWL conditions between 15 and 30cm below the peat surface, such as in February 2011 (-30cm), March 2011 (-16cm) and December 2011 (-17cm). Most of the fires occurred with shallow GWL conditions of 25 – 30cm below the peat surface, but fire occurrences with GWL of less than 5cm below peat surface strongly suggest that degraded peatlands are very vulnerable to fires even under relatively moist conditions. Therefore, degraded peatlands should be maintained in wet conditions, critical GWL less than 5cm below peat surface, to prevent surface peatfires. Dry conditions of degraded peatlands create suitable conditions for fires to burn downward and ignite deeper peat layers, resulting in devastating conditions with emissions in the area (Putra *et al*., 2016).

Given development of global climate policy and the high emissions associated with drained organic soils, it has been argued that rewetting and restoration of these soils should be included in mitigation strategies (Joosten *et al*., 2012; IPCC, 2014). Rewetting is the deliberate action of raising water tables in soils that have previously been drained for forestry, agriculture (crop production and grazing), water supply, peat extraction and other human-related activities, in order to re-establish and maintain water saturated conditions, *e.g.* by blocking drainage ditches, construction of dams or disabling drainage pump facilities. Rewetting can have several objectives such as nature conservation, GHG emission reductions and the promotion of leisure activities or paludiculture on saturated organic soils (Wilson *et al*., 2016a).

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 39cm below the peat surface, but that fire occurrences with GWL of less than 10cm 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 5cm to prevent surface peat fires from occurring.

Putra *et al*. (2018) showed that degraded peatlands lose their capacity to absorb and retain water from rainwater droplets, keeping them in drier than natural conditions for most of the year, and therefore are very vulnerable to fire. Rising Niño 3.4 STT anomalies predict significant fire risk that might yield large fire occurrences. Time lags between the low precipitation levels and resulting drops in GWL may also provide some abilities to predict fire risk in advance. Were proposed the critical GWL of less than 5cm below peat surface to prevent degraded peatlands from experiencing surface peat fires that may escalate to becoming devastating deep peat fires (Putra *et al*., 2018).

Groundwater level (> 40cm) can be used as an early warning system for risk of forest and land fire dangers (Silviana *et al*., 2019b) because peatland fire occurren 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 et al., 2019a, 2019b). The highest level of fire risk based on GWL > 40cm (danger category) is 99.63% in March, making this region very vulnerable to forest fires. GHG fluxes in rewetted organic soils 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*., 2016b).

However, there are currently active restoration efforts underway. Based on our field experience, these efforts, much like local fire teams, are effective but small-scale and underfunded. Indonesia has recently established a Peatland Restoration Agency with the goal of preventing peatland fires and restoring about 2 million ha of fire-damaged peatland across the nation. Although specific spatially-explicit target areas have not yet been identified, this agency could make peatland restoration more feasible by providing funding and capacity beyond that currently available in the region (Cattaua *et al*., 2016).

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Research clearly shows that regrowth of secondary peat swamp forest will benefit from these mitigation activities. Canal blocking results in a better environment for vegetation to grow up naturally through succession and increasing surface water levels during more of the year could help peat formation and retention. Aboveground biomass increases significantly in such areas compared to secondary peat swamp forest areas that are repeatedly burned (Saharjo *et al*., 2011).

Rewetting of organic soils results in a decrease in CO_2 and N_2O emissions as well as DOC losses and overall GHG emissions, calculated based on global warming potentials; but total CH_4 emissions are increased. Ultimately, carbon sequestration can be achieved by avoiding drainage of organic or peaty soils that are known to contain high densities of carbon, or by re-establishing high water tables in disturbed areas (Freibauer *et al*., 2004).

A study carried out in Pelalawan, Indragiri Hulu and Indragiri Hilir, Riau Province, revealed that it is difficult for farmers to follow the Government's zero-burning policy on peatland (Rohadi, 2017). As a result, a number of landowners decided to leave their farms as their harvests could not compensate for the high production cost of land preparation (Murniati & Suharti, 2018). 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 for the farmers' efforts in applying "zero burning" in land preparation, adequate incentives should be provided (Murniati & Suharti, 2018). Agustira & Ranola (2017) also stated that there is a need to provide incentives for smallholder farmers in implementation of sustainable oil palm plantations on peatland since the current situation of plantations in Siak District, Riau Province leads to greater social cost than social benefit.

Conclusions

Data and information taken from field research is really important and needed for better fire prevention management, reducing emissions of GHGs from peat fires, and bridging of policies and government regulations. Policies to be enacted by governments and subsequent implementation action and law enforcement need to be based in the scientific evidence gained in field research.

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