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# Alleviating peatland fire risk using water management trinity and community involvement

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**Abstract**. Conventionally, agriculture in peatland requires soil drainage to enable the crops to grow. This often results in being over-drained and makes it vulnerable to fires. The risk can be contained by applying water management trinity (WMT), which creates canals for water regulation and reservoirs instead of drainage. This study aimed to examine, elaborate, and validate the WMT effect and community involvement in minimizing fire risk in peatland. We collected water table depth every two weeks from 1 April 2017 to 31 December 2020 in a coconut plantation under WMT and employed Focus Groups Discussions (FGD) in five villages in Pulau Burung District, Indragiri Hilir Regency, Riau. The result showed that the existence of WMT for more than three decades has successfully maintained water table depth between 30 and 70 cm that is influenced by seasons. The fire occurrence based on the FGD interview has been validated with hotspot data from NASA's FIRMS. This research also employed SWOT analysis to examine the local fire mitigation strategy. The progress in lowering fire incidents and risk should be intervened with finding long-term solutions to increase farmers' capability on sustainable agriculture. Our finding reveals that the main strength in lowering fire risk is people's awareness in every village on the negative impact of land burning, along with the existence of WMT.

## 1. Introduction

Recurrent fires in peatland have been an intractable problem for many years [1, 2]. Between 2016 and 2020, more than 3 million hectares were burned in Indonesia without indication of decreasing pattern [3]. Historically, fire in peatland has been documented since the 15$^{th}$ century [4]. In Indonesia, the drought-induced by El Niño has become a major contributor to fires, especially during 1997-98 and 2014-16. Fires in 1997 emitted 0.81 to 2.57 gigaton of carbon (Gt C) into the atmosphere [4]. This amount surpassed 2015's fire [5].

Massive emission from peatland's fire is due to the soil's high carbon content. It is estimated that peatland in Indonesia stores carbon between 28 and 55 Gt C [6, 7]. Drained peatland is the starting point of the fire's problem as it removes water and turns the peat material dry. Irreversible drying due to peatland drainage led the soil to lose the ability to regulate and store water [8]. Consequently, peatland becomes more vulnerable to fires when drought hits. Lowering the water table is a common procedure in peatland agriculture to create an optimum condition for planting. Furthermore, drained peat soil followed by burn practice made the fires occur repeatedly. The burning practice was a passed down

local tradition to improve soil quality and acidity in easy and cheaper ways. Thus, the combination of drained peat, drought, and burning practice exacerbates the peatland fire.

Peatland fire is a complex phenomenon that requires all stakeholders' contributions to address the problem. In 2016, the Indonesian government established Peat Restoration Agency (BRG) to overcome the 2014-15's fires. However, the journey to minimize the fire risk in peat ecosystems is still a long way. One lesser-known solution is an integrated system called the water management trinity (WMT) applied on a coconut plantation in Riau. WMT is a closed water management system that utilizes canals not for drainage but for water regulation, reservoir, agriculture support, fire mitigation, and primary transportation system since the region is interconnected by canals (shown in figure 2). In short, WMT aimed to regulate water in the coconut plantation to prevent flooding during the rainy season and store water during the dry season.

This "undrained" water management system is believed to reduce fire risk in the area along with community involvement. Hence, this study aimed to examine, elaborate, and validate the application of WMT and community contribution in minimizing the risk of fire in peatland.

## 2. Materials and Methods

### *2.1. Study location*

This research was conducted in Pulau Burung District, Indragiri Hilir, Riau Province (Figure 1); this paper will use only Pulau Burung to describe the research area. It is located within 711,000 ha Sungai Kampar - Sungai Gaung Peatland Hydrological Unit (PHU). PHU is a peat ecosystem delineation coined by the Indonesian government for landscape management using at least two rivers or seas as boundaries [9].

Pulau Burung is an exemplary case where almost the entirety of its area consists of peat and the coconut agriculture practice there has successfully transformed the regional community welfare. This region on the east coast of Sumatra Island has had a long history of coconut farming in peatland since the late 19$^{th}$ century [10]. In the 1990s, Pulau Burung was a village destination for transmigration. Under the Nucleus Estate Smallholder-Transmigration (PIR-Trans) scheme, a company called Sambu Group facilitated coconut cultivation and its supply chain. Today, 10% of coconut plantations in Indonesia are located in Indragiri Hilir.

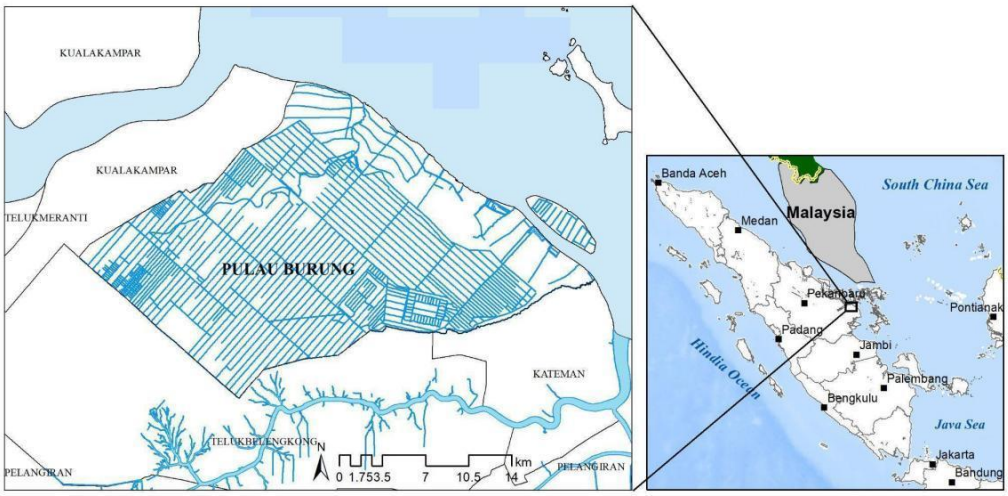


**Figure 1**. The map of study location in Pulau Burung, Indragiri Hilir, Riau.

### *2.2. Data Analysis*

This study used a descriptive exploratory method to achieve the research objective. To examine the application of the WMT, we collected and analyzed water table depth recorded by Sambu Group in one of 22,650 ha of their plantations. Water table data was measured manually every two weeks from April

2017 to 31 December 2020. In addition, validation through field surveys was conducted to elaborate further and the actual contribution of WMT in reducing fire risk.

To measure community change and involvement, we conducted several focus group discussions (FGD) in five villages in Pulau Burung District, namely Pulau Burung Village, Binangun Jaya Village, Manunggal Jaya Village, Suka Jaya Village, and Bangun Harjo Jaya Village. In-depth interviews within FGDs were conducted in July 2019. We interviewed 29 respondents from six categories, (1) farmer with ownership of land minimum 0.5-hectare, (2) landless farmer, (3) women farmer, (4) community leader, (5) trader, and (6) youth aged from 15 to 30-year-olds. We used open-ended questions about forest and land fires in Pulau Burung. In examining and elaborating the local's capacity on fire management, the following main questions were answered by respondents.

- How was the history of land and forest fires in the area?
- How is the fire's management in Pulau Burung?

The information from the interview about fire occurrence was then validated with data from NASA's Fire Information for Resource Management System (FIRMS). Active fire/thermal hotspot locations were collected from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) from 2001 to 2020. All the findings were interpreted using Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis to disseminate finding results. The analysis included developing strategies as recommended action on fire management in Pulau Burung [11].

## 3. Results and Discussion

### *3.1. Effect of water management trinity to fire risk*

On its initial establishment, the company designed and built the WMT as an integrated water resource management that has maintained and functioned until today. WMT is different from the common "drainage" water management system in peatland [12]. The system was designed to keep the soil moisture for agronomic function, ensure freshwater supply, mitigate fire, and accommodate water transportation. Figure 2 shows that the reservoir canal provides a massive amount of water in the ecosystem.

**Figure 2**. The reservoir canal in Pulau Burung.

The WMT has been operating since the beginning of the plantation development in the mid-1980s. Hence, WMT existed before the Government Regulation (PP) No 57/16, which controlled peatland water tables, was issued [13]. For more than three decades, Sambu Group has maintained WMT to run effectively. It resulted in positive impacts both on the environment and social economy. The system proves that it is possible not to drain peatland for agricultural purposes, thus lowering the risk of peatland fire.

The direct consequence of maintaining WMT in Pulau Burung is a regulated water table in the area, which positively minimizes the risk of fire. The WMT can maintain water table depth around 30 to 70

cm due to seasonal variation. Figure 3 indicates the water table depth since 2017-2020. During 2019's Indonesian forest and land fire disaster, which coincides with a prolonged drought season, the WMT has managed the water table not to exceed 71-cm, which is adequate to allow productivity while preventing fire risk.

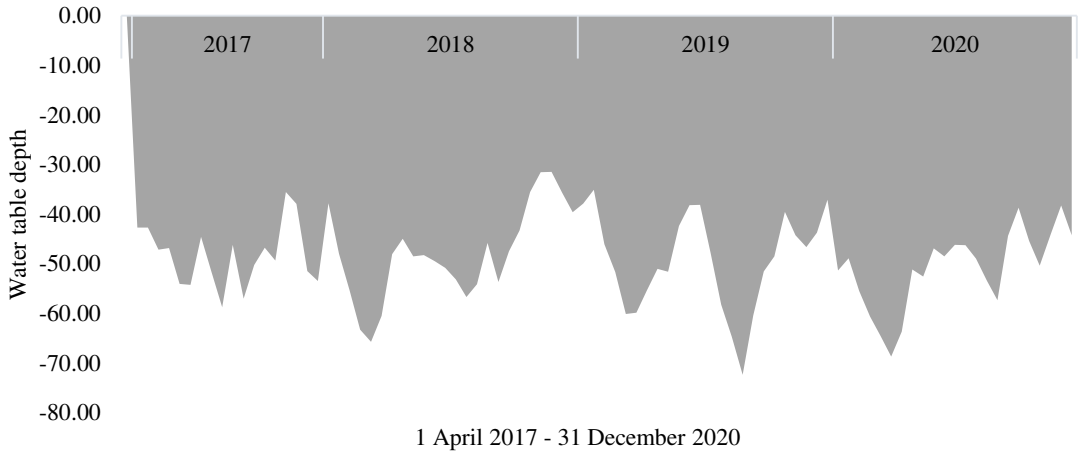


**Figure 3**. Water table depth monitoring in 2017 to 2020. It shows water table depth change due to seasonal variation.

The massive forest and land fire had happened because drought made it difficult to obtain water and enabled the fire to spread widely in dry vegetation and peat soil. After the mass forest and land fire happened in 2014-15, the Indonesian government, through Government Regulation (PP) No 57/2016, regulated water table depth with a 40-cm threshold as a requirement on peatland utilization to maintain peat soil moisture [13]. Although the regulation lacks scientific evidence and clear measurement parameters and conditions, it supports the idea of high water tables' significant contribution in preventing fire. For the same reason, the data available in this study is dated to 2017, after the regulation was advocated widely.

*3.2. Shifting habit and community involvement*

This study concluded two main factors that played important roles in fire management at the community level; first, the community commitment to reduce land burning for clearing. In the five villages, the answer from respondents has the same pattern: It was a common practice for burning the land for cheaper land clearing and improving soil acidity. However, the intensity has been reduced in recent years since the government enforced strict regulations to control forest and land fires. As a result, the community was prohibited from burning their land, especially in drought season.

In the early prohibition, communities ignored the warning from the government. However, their perception and habit slowly changed after one of their members had been prisoned due to land burning. The Indonesian National Military (TNI) and police undertook grassroots-level socialization and campaign regarding the menace of fire in their land, which drastically shifted the community habits. They also installed billboards or posters, spreading the law enforcement on fire management with hefty penalties such as fines and jail time for those who broke the laws. Consequently, the statutory compliance to reduce land burning improved. The community, especially farmers, has to find a way to manage their land without burning it. According to one farmer during FGD, the fear of fines and jail time worked since the last fire incident was in 2016. The village-level government also initiated community group patrols that monitor the hotspots in their areas. Table 1 provides further details on the key messages from the FGD interview with local communities.

**Table 1.** The descriptive result from FGD.

| Respondents' categories | Key messages |
|---|---|
| Farmer | ▪ Fire in 2004 in an abandoned land due to cigarette butt.<br>▪ Almost 2-3 years without land fire (the survey was conducted in 2019)<br>▪ The existing law has a big impact on the people (especially since the law enforcement gives very strict and frequent socialization)<br>▪ Even if fires occur in plots, the people will work together to put out the fire (*gotong royong)* |
| Landless farmer | ▪ The worst forest fire was observed by the farmers back in 1999<br>▪ Forest and land fires can still be spotted in the area, but not as frequent as before the law was enforced<br>▪ The *Babinsa* (village supervisory non-commissioned officers) have been effectively playing important roles in controlling land and forest fires<br>▪ The local people have been showing a high willingness to cooperate with the *Babinsa* |
| Women farmer | ▪ There was little fire a long time ago, but it happened because someone burned the land secretly<br>▪ Farmers burn the land to decrease the soil acidity<br>▪ There was a case, and a farmer burned his own land. However, the fire got bigger and caused a land fire. He is still being punished and went to jail in Pulau Burung village |
| Community leader | ▪ Previously, farmers burned the peatland fertile the acidic soil for agriculture. But they do not do that anymore<br>▪ Since continuous socialization from local police departments, *Babinsa*, and *Koramil* (Military District Command Sector), people are afraid to burn the peat anymore. It is because of the penalty they must pay if they get red-handed when they burn the land<br>▪ When the fire happens, the villagers always initiate to put the fire out before the forest patrol comes to the hotspot<br>▪ The villagers must spend extra money for the unofficial stipend and consumption for the firefighter. |
| Trader | ▪ Developed community-based firefighting group<br>▪ There is sanction and fine if an area is burned like in Binangun Jaya Village.<br>▪ Volunteerism effort to address fire<br>▪ TNI engaged the community and installed billboards about the danger of land & forest fire. |
| Youth | ▪ No forest fires in their villages, but they sometimes found it happened in the other areas<br>▪ Good awareness in avoiding forest fires<br>▪ No village regulation on forest fire<br>▪ They had socialization of forest fire prevention provided by the police and *Koramil*<br>▪ *Babinsa* helps to control forest fires<br>▪ The equipment is provided<br>▪ No fire during drought season |

Collective responsibility also became the second factor in extinguishing the fire. This is as part of community awareness in preventing forest and land fires in their village. If a fire ignites and burns a larger area, it will become a law violation to villagers. So, the villagers will manage to put the fire out

before being spotted by TNI and police when the fire happens. Besides community initiatives, the local company also developed a firing squad with more advanced equipment to extinguish the fire. The communities and the firing squad have worked together to prevent and keep the fire under control, which the village government supports.

*3.3. Validation from Remote Sensing data*

According to the interview, one farmer said that the last time the area experienced severe fires was in 2004, where an abandoned land was on fire caused by cigarette butts. However, from the field survey in 2019-2020, practices of controlled burning of coconut waste were also observed several times. Both events differ because actual fire occurs in an abandoned land for a significant amount of time. Meanwhile, the other practice is a habit that produces small and short-time fires with more lasting smoke. This study attempted to validate the information from the interview with actual data hotspots extracted from satellite images.

Figure 4 shows the total number of hotspots from FIRMS data in Pulau Burung. This higher number of hotspots matched the information from the farmer's interview, especially in the period 2004-05. The graph also indicates the number of hotspots in Pulau Burung, mirroring the hotspot in Riau Province. This Province is known for forest and land fires which caused a haze to neighboring countries. Even though the number of both hotspots is alike, the intensity of the fire is different. Based on field research, we found the hotspot recorded in Pulau Burung was short-period burning of coconut husk or controlled burning for farm preparation. The hotspot will be suppressed at the end of the day without leaving burned scars on the peatland. It is different compared to fire in Riau Province which occurred in dried peatland and caused a large area of burned land.

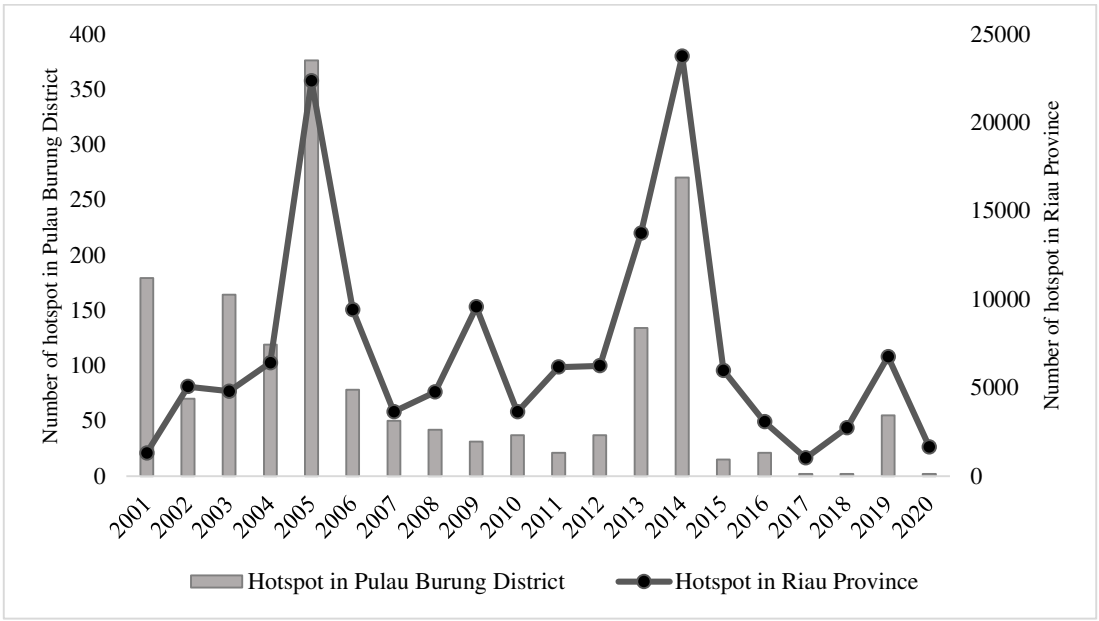


**Figure 4**. The number of hotspots from FIRMS data from 2001 to 2020. The left axis shows hotspot numbers in Pulau Burung, and the right axis shows hotspot numbers in Riau.

This research found that El Niño is not the only main contributor to massive forest and land fires. Therefore, the relevance between the number of hotspots and the intensity of El-Niño should be aligned. Meanwhile, the hotspot data shows the peak in the weak El-Niño in the period 2004-05. After that period, the second-highest fire was in 2014-15's El Niño. In 2013, a non-drought year without climate anomalies, the massive fires also happened [14]. However, in the moderate El-Niño period in 2009-10, the number is low compared to the weak El Niño in 2004-05, 2014-15, and 2018-19. Hence the primary source of fire is anthropogenic. After El Niño in 2014-15 and regulation change, significant hotspot

reduction was recorded by satellite. In 2017, 2018, and 2020, the hotspot is far less compared to previous years. In 2019, after this research was conducted, El Niño induced drought in Indonesia, but the hotspots were far less than in previous events.

Figure 5 below shows the distribution of hotspots from NASA's FIRMS in Pulau Burung, Indragiri Hilir, in the last five-year period, 2016 to 2020. It reveals that the hotspots inside WMT are much fewer compared to areas without WMT. This is because the burning practice caused the hotspot agglomeration in the northern area during 2016 and the sparks flew into WMT's area. On the other hand, our field visit and interview found no burned area inside WMT, despite the satellite spotted hotspot. This is because the local practice governs people to extinguish fires at night. Meanwhile, the temporal resolution of the MODIS satellite only allows fire recording during the daytime. Therefore, it must be underlined that the recorded hotspot does not cooperate with the burned area since the records are from the daytime when the fire is present instead of the following day when the fire is often extinguished at night [15].

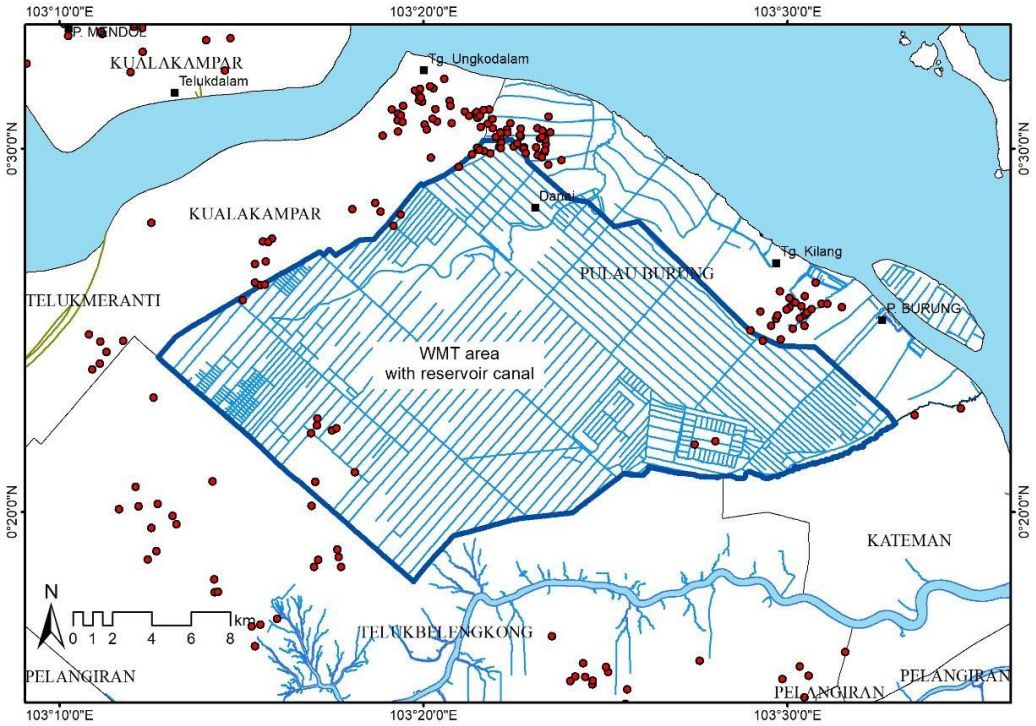


**Figure 5**. The map of hotspot from FIRMS in period 2016 to 2020. It shows the area within WMT has less hotspot compared to other plantations outside. The hotspot in this map does not represent the burned area in the field.

*3.4. SWOT analysis*

Table 2 below indicates the SWOT analysis of peatland fire management in Pulau Burung. We found that the main factor in lowering fire risk is people's awareness in every village about the negative impact of fire, especially on their coconut plantations. Fire generally does not naturally occur, and it must be ignited by humans on purpose or by accident. A study found that the community knew the cause of forest and land fire, and 82% blamed human imprudence while burning their land for agriculture [16]. As an actor of agriculture in Pulau Burung, raising people's awareness is an essential asset in fire management. This awareness is also enforced by all stakeholders, such as government, private companies, and involvement of TNI and police, which make strong alliances in alleviating fire risk. The presence of WMT strengthens the alliance in preventing fire in peatland. It means the fires are unexpected but might occur or are expected to occur on a rare basis. However, it will quickly be extinguished because of high soil moisture and water availability in the canals. In many cases, the extended periods of massive forest and land fire in peatland happened due to a lack of water access.

In practice, as an internal weakness, the communities still conduct controlled burns in managing their lands or burning excess coconut waste (husk, leaf, etc.) at their yards. Removing coconut husk through burning is optional, although abandoned husks would attract pests. Sometimes, the farmer cut the grassland below the coconut tree, collected it into a pile, then burned it. Even though this practice is inevitable, the farmers try to use less fire if possible. However, the smoke from these activities can be spotted as a hotspot from the satellites. Sometimes, these activities spread and burn bush and scrub around. This activity is driven by the limited knowledge of farmers in practicing sustainable agriculture. It is a hereditary tradition that burning the land will improve soil quality for farming. There is an unwritten regulation that allows burning practice only in the rainy season to address this issue. Thus, they are aware of minimizing the risk of fire, especially in the dry season. Additionally, to use less fire in managing the land, including controlled burning, the village government and the community created a special team to monitor fires that show up.

**Table 2**. SWOT analysis of fire management and its strategy.

| **Internal Factor** / **External factor** | *Strength*<br>- People's awareness of the bad impact of the burning practice has been increased<br>- WMT provides biophysical aspects that naturally prevent fire<br>- The design of WMT involved a fire management system that provides easy access to vast water resources in the reservoir canals<br>- Involvement of all stakeholders, not only TNI and Police, but also village offices, private companies, and NGOs | *Weakness*<br>- Requires significant funding for WMT maintenance<br>- Farmers still conduct small-scale controlled burning to manage their land.<br>- Not all farmers have the capacity and capital to manage their land sustainably |
|---|---|---|
| *Opportunities*<br>- All stakeholder supports the effort in minimizing peatland fire in Pulau Burung<br>- The trend of fire occurrence is low since the source of fire risk was reduced | S-O strategies<br>▪ Maintaining the awareness of people not only because of fear from the laws but to do burn-free practice is a necessity<br>▪ Maintain lower fire occurrence through regular reports and patrol, and create more reservoir canals in smallholder plantation | W-O strategy<br>▪ Moving forward to create a long-term solution through improving the capacity of farmers on sustainable agriculture |
| *Threat*<br>- Periodic drought season induced by El Niño events<br>- Accidental fire could happen, such as from cigarette butt or spark from the controlled burn | S-T strategies<br>▪ Keeping the good infrastructure of WMT<br>▪ Improve awareness and knowledge to prevent accidental fire in their plantation | W-T strategies<br>▪ Increase campaign and prohibition of using fire when El Niño hits<br>▪ Raising the frequency of patrol in vulnerable areas |

The trend of low fire occurrence should be maintained in all seasons in the future. We found that in normal conditions without El Niño, the fire risk in Pulau Burung is nearly zero. However, it is hard to entirely eliminate the fire risk because accidental sources of fire could happen, such as from cigarette butts. During El Niño events, the risk will increase occasionally or even probably will occur often. Nevertheless, the villagers have special teams for fire prevention and management. This means the risk most likely will not be high, or even during El Niño, the fires will not frequently happen.

In developing strategies for alleviating fire risk in peatland, the chance and opportunity are wide open. The action from the government in controlling and enforcing fires in peatland makes the farmers

have to find a way to farm their land continuously. Besides maintaining good progress in lowering risk and incident of fire, developing long-term solutions to increase farmer capacity on sustainable agriculture is also important.

Minimizing fire risk and incidents in peatland is compulsory to promote sustainable agriculture. The use of an integrated water management system and burn-free farming practices have successfully reduced the number of hotspots. In practice, both of them should work in parallel because if we only work on one aspect, the fire risk would remain high. The necessity to minimize fire in peatland is imperative, particularly because Indonesia is ranked among the largest carbon emitters in the world due to intense and massive forest fires which accelerate climate change [17, 18].

Low fire occurrence in recent times has been achieved after PP No 57/2016 issued. In practice, two reasons explain this regulation is not optimal yet. First, to employ 40-cm water table depth requires integrated water management. Sudden issuance of the policy forced many companies to rewet their plantations hastily or did canal blocking to achieve 40-cm water table depth. In drought season, the water table will drop due to the disintegration of the system. Second, peatland utilization for agriculture started a long time ago without proper guidelines. Thus, it is hard to apply as it needs to break the habits of common agricultural practice. A sense of fear in the community due to the involvement of TNI and police is not a permanent solution. However, it is a good start to include sanctions and intervention to reduce peatland fire effectively [19].

It is impossible to banish all of the fire in peatland. However, eliminating risk is a visible way to minimize fire in peatland, even during El Niño season [20]. Drawing back to the 1997-98 fire incident, at least 176 companies contributed to igniting fires that caused enormous forest and land fires [21]. Also, several companies had been sued by the Indonesian government for causing the 2014-15 fires. Law enforcement among violating companies is crucial to prevent large fire occurrences. In fact, the government and private sectors should work together to design effective integrated water management that is tailored to their specific areas. A WMT system in Pulau Burung could be a technical reference and/or study case on how the canals, dikes, and dams with water gates can work as an efficient mechanism to regulate water in any season. It can be applied to maintain the soil's moisture level to prevent fire and enable the crops to grow.

## 4. Conclusion

The community commitment to reduce land burning for clearing and collective responsibility to extinguish the fire have successfully controlled fire incidents. The WMT also played an important role for more than three decades in maintaining peatland quality and minimizing the risk of fires. The information gained from the FGD regarding lower fire incidents has been coherent with satellite observations. However, the SWOT analysis concluded that the community tends to fear the sanction, which led them to shift their burning habit. They also have formed fire patrol groups to monitor fire incidents at the village level. However, improving their cultivation methods is still needed to prevent the burning practice from happening again. Furthermore, further study and development programs are essential to identify a long-term solution to sustainable agriculture practice which uses less fire.

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