The Spanish Review of Financial Economics

www.srfe.journals.es

CONTRIBUTION OF WEATHER MODIFICATION TECHNOLOGY FOR FOREST AND PEATLAND FIRE MITIGATION IN RIAU PROVINCE

TUKIYAT TUKIYAT[a], ANDI EKA SAKYA[b] and F. HERU WIDODO DAN CHANDRA FADHILLAH[c]

[a,b,c]The National Research and Innovation Agency, PUSPIPTEK Serpong, South Tangerang, Banten, Indonesia.

Abstract

Peat and forest fire has become an annual disaster and one of which is due to low rainfall. The highest insecurity of forest and peatland fires thus occurs in the dry season where rainfall is very low and the intensity of the sun is high. The smoke and carbon emitted result in rising air temperatures and causing global warming. Mitigation and control measures before it happened is necessary. Weather Modification Technology (WMT) serves as one of technological solutions to control forest fires by increasing rainfall in potentially affected locations. This study aims at examining the level of effectiveness of WMT performance in mitigating forest fires in Riau Province conducted in 2020 measured by rainfall intensity, hotspots decreased and land water level increased. We used descriptive and inferential statistical approaches using Groundwater Level (GwL) measured data as the parameter for forest and land fire mitigation. The peatland flammable indicator is when the water level is lower than 40 cm below the surface of peatland. In addition, we also utilized rainfall, surface peat water level, and hotspots. The study was conducted in Riau Province on July 24 – October 31, 2020. The results showed that the operation of WMT increased rainfall by 19.4% as compared to the historical average in the same period. Rainfall triggered by WMT contributed to maintain zero hotspots with a confidence level of > 80%. The regression analysis of GwL to rainfall (RF) as depicted by Gwl = - 0.66 + 0.001 RF which shows positive correlation between the two and thus confirm that WMT can be used as a technology to mitigate forest and land fire disasters.

Keywords: Peatland, Fire, Weather Modification, Groundwater Level.

INTRODUCTION

Forest and land fire is one of disasters caused by natural factors or caused by human actions (Wahyunto, Sofyan Rintung, Suparto, 2004). Community activities in processing agricultural land/plantations using slash and burn method is one of the factors that cause forest and land fires in Riau Province (Yusuf et al., 2019). Forest and land fire disasters belong to the hydrometeorological disaster group. BNPB data (Jati, 2021) in January 2021 showed that 98 percent of disaster events were triggered by hydrometeorological factors. Although hydrometeorological disasters are quite frequent in event, the death toll exposed was less than the victims caused by geological disasters. Hydrometeorological disasters can lead to loss of life, injury, decreased immunity or health, property damage, loss of livelihood and services, social and economic disruption, or environmental (Chauhan et al., 2013) damage. This study aims at examining the level of effectiveness of Weather Modification Technology (WMT) performance in mitigating forest fires in Riau Province. Forest and peatland fires in Indonesia, especially in Riau, have caused enormous damage. Forest and land fires will bring also an negative impact in forest ecosystems and biodiversity and declining environmental quality (Itsnaini, 2017). Global Wetlands Data (April 16, 2019) figured out that Indonesia process the second largest peatland in the world with an area of

22.5 million hectares (ha) and ranks the second in the world after Brazil with an area of 31.1 million hectares. The provinces with the largest peatlands are Papua with 6.3 million ha width, Central Kalimantan (2.7 million ha), Riau (2.2 million ha), West Kalimantan (1.8 million ha) and South Sumatra (1.7 million ha). In addition, West Papua (1.3 million ha), East Kalimantan (0.9 million ha) and North Kalimantan, North Sumatra and South Kalimantan each of them has 0.6 million ha. Indonesia's peatlands bear the potential to become a source of natural wealth and a strategic role for the environment, among others, saving 30% of the world's carbon, preventing drought and preventing the mixing of salt water in agricultural irrigation.

Aldrin et al. (2003) described that Indonesia has 3 characteristics of rainfalls. First, most areas of Indonesia have the characteristics of minimum rainfall from April to October with the peak of the dry season (minimum rainfall) in August - September and is known as the tropics. Second, areas that has two minimum rainfalls, namely, in February, March and April (FMA) and then in July, August, September and October (JASO) and known as equatorial rain characteristic region. This equatorial rainfall characteristic area occurs in the eastern region of Sumatra around the equator. While the third one is an area that has rain characteristics opposite to the tropics.

In the period of low rainfall conditions, it has the potential to produce hot spots that can lead to forest fires. This condition is further exacerbated since Riau province is a vast peatland. In the dry season, the occurrence of forest and peat land fires is very prone that lead to a huge amount of harmful haze. To avert and combat massive and sustainable forest fires, it is necessary to involve all stakeholders, starting from the government, community, business world, education in the form of a pentahelix synergy. One of the technological solutions to prevent forest fires is the implementation of the Weather Modification Technology (WMT). Through Presidential Instruction No. 3/2020 concerning Forest and Land Fire Management, WMT denotes as one of an affirmative solution to lessen forest and land fire losses. Furthermore, the Presidential Instruction assigned Agency for the Assessment and Application of Technology (BPPT) to carry out WMT and develop land clearing technology without burning to combat forest and peatland fires. This study aims at examining the level of effectiveness of WMT performance in mitigating forest fires in Riau Province conducted in 2020, as measured by rainfall intensity, decreased hotspots and increased land water level.

DATA AND METHODS

The focus of this research is on the performance of WMT activities from July 24 to October 31, 2020. This research utilizes both primary and secondary data. The primary data was the rainfall measured at the area of location where WMT activities take place. Secondary data is in the form of hotspot data from MODIS-NASA (Moderate Resolution Imaging Spectroradiometer-Nasa), rainfall from the TRMM (Tropical Rainfall Measuring Mission) satellite, and peat water level data from Peat and Mangrove Restoration Agency (BRGM). Figure 1 shows a map of WMT coverage area in Riau Province at the period of forest and peatland fires prevention operation.

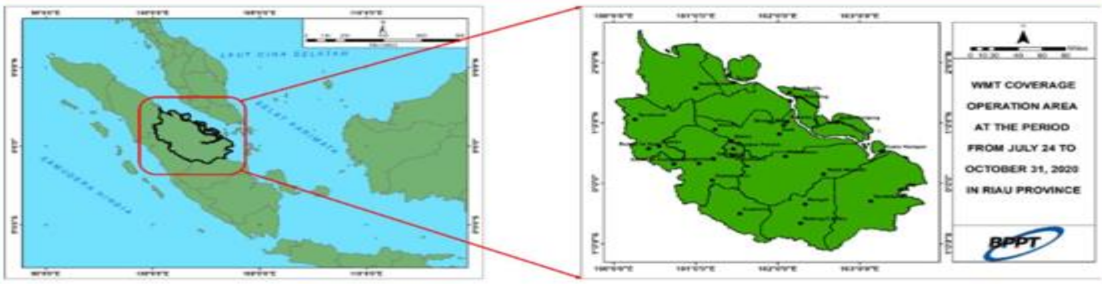

Figure 1. WMT coverage operation area at the period from July 24 to October 31, 2020 in Riau Province.

Data patterns of rainfall, hotspots, peat groundwater level were analyzed using descriptive statistical methods. The rainfall pattern observed during the operating period is compared with historical rainfall data from the Meteorological, Climatological, and Geophysical Agency (BMKG). Formula (1) describes a summing-up of WMT performance, as follow:

$$P_{WMT} = \frac{RS_{WMT} - HAR}{RS_{WMT}} \text{ x } 100\% \qquad (1)$$

where:

PWMT = WMT Operating Performance (%), RSWMT = Rainfall Resulting from WMT Operations (mm), HAR = Historical Average Rainfall (mm).

Inference statistical analysis is performed utilizing a regression model. This model illustrates a functional relationship to determine the amount of rainfall contribution from WMT towards peatland water level changes in Riau Province. The basic and simple regression model is used:

$$\hat{Y} = \alpha + \beta \text{ RF} + C \qquad (2)$$

where $\hat{Y}$ is Groundwater Level (GwL) (cm), α is a constant, β is coefficient of regression/contribution of rainfall to peatland groundwater level, RF is Rainfall (mm/10 days), and Ɛ is error term.

Results and Discussion

Data Data Description

Cloud seeding was carried out using the Casa 212-200 aircraft belonging to the Indonesian Air Force Squadron 4 (Figure 2) Malang from July 24 to October 31, 2020.

(a) (b)

Figure 2. Cloud seeding operation using aircraft. (a) Aircraft towards cloud growth target area, (b) Cloud seeding operation.

Technically, WMT is done by spreading the cumulus cloud using seeding material, NaCl, through the aircraft. The seedling material stimulates the growth of raindrops thereby accelerating the occurrence of rain with an increased intensity as compared to natural rain. Table 1 Describes WMT's operational data and result during the research period.

Table 1. WMT operating results

Description	Sum
Released Flights	71 Sorti
Number of flying hours	101 Hours 10 minutes
Total seeding materials	56.800 kg
Rain Yields	290.3 million m^3

The main objective during WMT operations was to augment the rainfall to mitigate forest and peatland fires in Riau Province. This operation was supported by aircraft of Cassa 212-200 owned by TNI Squadron 4, based in Malang. During the mission, 71 sorties of flight to seed the cloud. It took 101 hours and 10 minutes of flying hours. And, it dispersed 56,800 kg of seeding material. The rain harvest measured during the TMC operation was 290,3 million m^3. The value of the rainfall volume was calculated by measuring the thickness of the cloud targeted by WMT multiplied by the coverage seeded area. Figure 3 illustrate the rainfall volume measured during WMT mission.

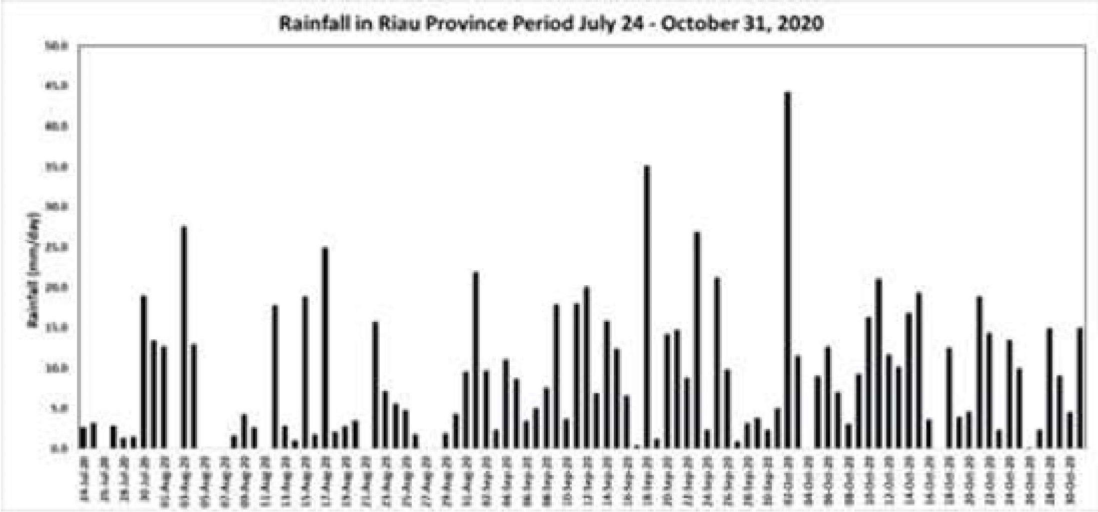

Figure 3. Rainfall chart in Riau Province period July 24 – October 31, 2020.

The pattern depicted in Figure 3 obviously illustrates light to moderate rain observed almost every day with intensity of 1 mm to 44 mm. The highest rainfall measured on October 2, 2020 at 44.2 mm. The result of this rain was certainly very useful to wet peatlands area in Riau Province to curb potential burning.

The falling rain may serve to extinguish the fire. Sandhyavitri et al. (2018) found that the WMT increased the rainfall rates by 8% as compared to the prior three years averaged within the study area. The effectiveness of the performance of WMT activities is evaluated by comparing the measured rainfall during the mission with those of historical and prediction rainfall data from Meteorological Climatological and Geophysical Agency (BMKG). The comparison illustrates the escalation of rainfall of 19.4% as opposed to the historical data and shows 12.4% of increment as compared with the rainfall value predicted by BMKG.

Table 2. Rainfall evaluation results.

Description	Rainfall (mm)		
	Actual Rainfall with WMT intervention (Gsmap)	Average Historical Rainfall (2009-2019)	Rainfall Prediction BMKG Data (Period July 24 – October 31, 2020)
Total Rainfall During WMT Period July 24 – October 31, 2020	545.4	439.4	477.9
Bulk Increase Added Value		19.4%	12.4%

Source: BBTMC Processing Results, 2020

To accurately evaluate the effect of rainfall augmentation, Wu and Yan (Wu et al., 2018) suggested the need to plot the identified affected area in according to the cloud characteristics on the duration of operation. This study attested that the application of WMT successfully enhanced rainfall in the observed area. The results of this study re-emphasize the study (Ari Sandhyavitri et al., 2020) which described that WMT operations in Riau Province from 2014 to 2016 showed successful performance based on the evidence of PCH>1.00. This additional rain has certainly brought an impact on the level of wetness and, in turn, reduces the potential flammability of the peatlands.

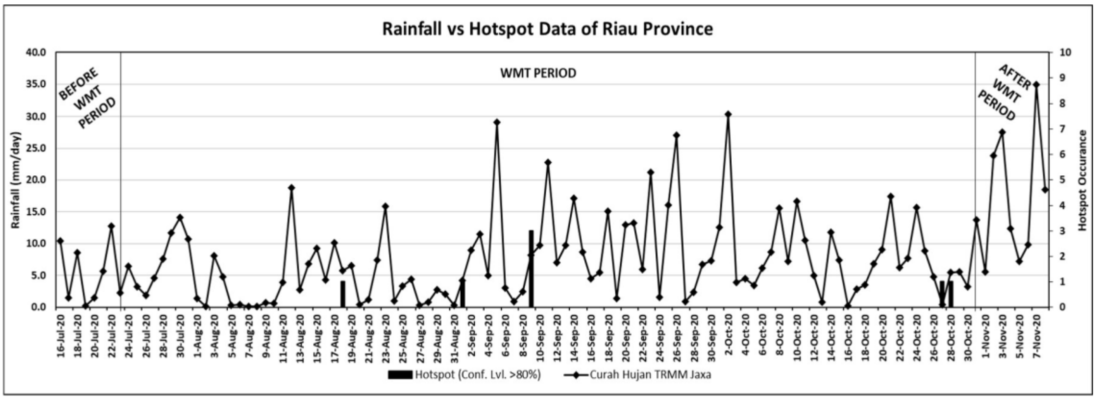

Figure 4. Relationship between rainfall and hotspot, period July 24 – October 31, 2020.

Hotspots are indicators of potential forest and peatland fires. Based on Figure 4 explained that rainfall can decrease hot spots. The additional rainfall resulted during the mission effectively preserve number of hotspots close to zero (>80% confidence), and only a few days of new hotspots appear, although still in small numbers. This can be related to the condition of the no rainy days, which thus increased the potential for flammability. Despites, the additional rainwater generated by WMT during the study period effectively maintain the number of hotspots below 10 points and thus function well in taking care of the flammability potential even lower.

This study also noticed that during the period of the operation, the number of hotspots were kept low with confidence level of 80%, stable, and showed any significant fluctuation or escalation till the end of October 2020. Further, BMKG predicted that the onset of rainy season in Riau Province was due in November 2020. During the rainy season, the amount of precipitation got more increase naturally. Because of natural rains have seemed to bring effective influence on curbing the hotspot and wetting of peatlands, thus inhibit the potential of flammability. Implementation of WMT could thus be stopped.

Effect of Rainfall on Peatland Groundwater Level

Peatland is a multifunctional natural resource, including hydrology regulators, absorbers and carbon storage that can dampen global climate change. Groundwater Level (GwL) serves as an indicator of the occurrence of fires in peatlands, in addition to other factors such as rainfall and hotspots, that cause fire events. To maintain GwL at peatland area in Riau province requires rainfall. Conceptually, sufficient rainfall will increase GwL at peatland area in Riau Province.

The GwL is monitored by tools owned by BRGM (Peat and Mangrove Restoration Agency). There are 9 GwL observation points in Riau Province, namely in Rokan Hulu, Rokan Hilir, Dumai, Bengkalis, Siak, Kampar, Pelawanan, Kepulauan Meranti and Indragiri.

Table 3. Observation of GwL data patterns in Riau Province.

Region	GwL Peatland		
	Start	End	Trend
Rokan Hulu	-0.47	-0.17	Up
Rokan Hilir	-0.18	-0.57	Down
Dumai	-0.29	-0.35	Down
Bengkalis	-0.67	-1.26	Down
Siak	-0.54	-0.54	Stay
Kampar	-0.44	-0.44	Stay
Pelalawan	-0.62	-0.67	Down
Kepulauan Meranti	-0.64	-0.50	Up
Indragiri	-0.92	-0.77	Up

Table 3 shows the status of GwL measure at those 9 locations of monitoring. During the mission, the augmented rainfall seemed to effectively upsurge the GwL as measured at 3 locations namely, in Rokan Hulu, Meranti Islands and Indragiri. The measured GwL at other 4 locations appeared continue to decline and there are 3 locations whose elevation remains. This might be related to two facts. The first was due to the absence of rainy days in those locations which related to the current season. And the second was caused by the fact that peat in Riau Province owned deep and very deep characteristics. This research found that the application of weather modification technology could increase precipitation occurrence and significantly reduce peatland fire in Riau. The increasing rainfall value (PCH) in Kepulauan Meranti Regency were 1.019, 1.08, 0.68, and 1.649 during four times WMT operations from 2014 to 2016 Despite those fact, the mission successfully poured the rainfall at 3 out of 9 locations and maintained GWL above the hazard limit of -0.40 meters. The significant liven up of GwL in Meranti district was also noticed, however, the volume of water outpoured in that location yet not effectively raise the GwL above the hazard limit of 0.40 meters. The wetting process as a direct impact of WMT improves the peat hydrological system which is messed up by the continuous no-rainy days. The peat will remain wet. The rate of degradation and the potential for peat fires can thus be prevented.

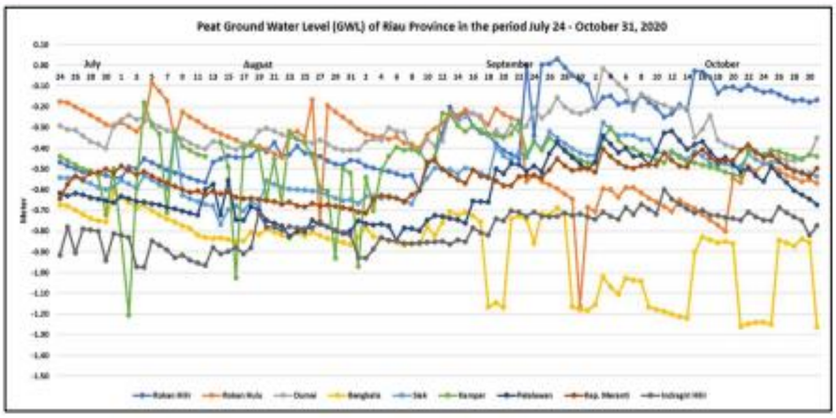

Figure 5. Peat Ground Water Level in Riau Province in the period July 24 - October 31, 2020.

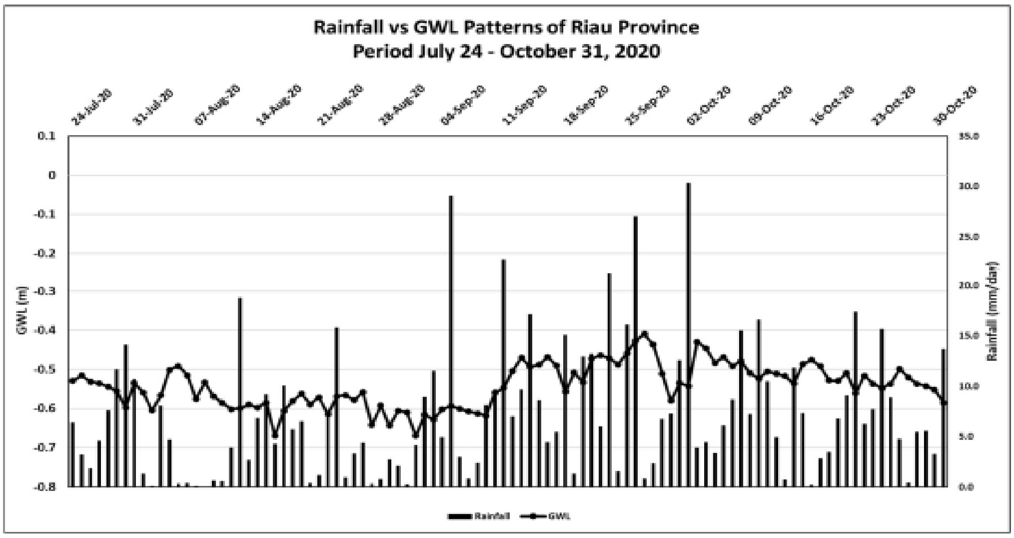

Figure 6. Chart of GwL relationship patterns and daily rainfall in Province Riau, observation period July 24 - October 31, 2020.

The statistically checked was further conducted to observe the level of significance of the correlation between contribution of water outpoured by WMT (rainfall) with the augmented GwL at measured locations. The evaluation was carried out based on regression modelling. The regression model of the effect of decades rainfall on GwL can be modelled as $\hat{Y}$ = -0.66 + 0.001RF. The coefficient value of the constant is negative. This indicates that if there is no rain, Gwl is -0.66. This value illustrates the threshold at the easiness level of which peat is getting easily burnt. The value of -0.66 has been well below that of -0.40 as the GwL threshold. The magnitude of the rainfall contribution from WMT is indicated at the regression coefficient value of 0.001. Regression coefficient value of 0.001 means that to increase 1cm it takes rain of 100 mm for 10 days continuously. The results of the regression coefficient test by α=5% are insignificant where the sig-p value of the study results of 0.087 is still greater than the value of 0.05. However, this regression model will be significant at α=10%. WMT could increase precipitation occurrence and significantly reduce peatland fire in Riau (Sutikno et al., 2020)

The magnitude of the direct influence of the contribution of rainfall of WMT to GwL can be analysed with the path analysis model shown with beta values. The path analysis model of the influence of rainfall on GwL can be shown as $\hat{Y}$= 0.567RF. The path coefficient value of 0.567 means that rainfall of WMT has a direct effect of 56.7% against GwL. The goodness of fit of the modelling was shown at R-square value of 0.322 which means that the diversity of GwL can be explained by rainfall of 32.2%, while the remaining 67.8% of GwL diversity is explained by factors other than rainfall. The results of the analysis of the correlation between rainfall and GwL amounted to 0.567. There is a positive correlation between rainfall and GwL with medium categories.

CONCLUSIONS

This study reports the performance evaluation of WMT operation conducted in Riau Province from July 24 - October 31, 2020. The mission of WMT effectively increased rainfall by 19.4% from the historical and 12.4% from rainfall prediction. The correlation between the GwL and rainfall is GwL = -0.66 + 0.001RF. The coefficient of constant -0.66 indicates if there is no rain then the GwL will decrease by 0.66 cm. The contribution of rainfall to GwL of 0.001 means that to increase the GwL by 1 cm it takes 100 mm of rainfall in the region for 10 days continuously. There is a positive correlation between rainfall of WMT and GwL which is 0.567. This means that if rainfall of WMT increases it will affect the increase in GwL. The rain harvested significantly enabled to upsurge the GwL of peatland in Riau Province. The GWL in Rokan Hulu, Meranti and Indragiri Islands noticeably increase, while others were continuously decrease, though still within the threshold.

Based on the results of these conclusions, to improve the operational performance of WMT, it is recommended that some of the following: (1) the implementation of WMT activities must be carried out in a timely manner that is done in the transition season where in the transition season the existence of clouds is still potential enough to be seeded, (2) it is necessary to coordinate between relevant agencies in the prevention of forest and land fires in an integrated manner, (3) There needs to be a ready-made budget at any time of disaster and WMT operational movements can be done on time.

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