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The roles of weather modification technology in mitigation of the peat fires during a period of dry season in Bengkalis, Indonesia

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Abstract: The annual peat fire disasters have suffered human life, deteriorated peat land ecosystems, and caused severe economic losses in Indonesia, Malaysia, Brunei, and Singapore during a period of 2014-2016. The objective of this study is to investigate to what extent the weather modification technology (WMT) may play its roles in increasing the precipitation rates in order to mitigate the peat fires disaster in Bengkalis, Riau Province, Indonesia. The study obtained the precipitation rates data from the tropical rainfall measuring mission (TRMM) satellite during the period of 2014, 2015 and 2016. The data then statistically analyzed using the Grads software package. While the process of WMT at the designated research location was evaluated together between the Artificial Rain Unit of BPPT (Agency for the Assessment and Application Technology), and the Engineering Faculty, University of Riau, 2016. The research showed that the WMT increased the rainfall rates during the dry season within the study area by 8% (520.7 mm to 557 mm) in the 3 months period (July 14 - October 6, 2016), and reducing significantly hotspots by 88.6% from 6.725 in 2014 to 770 in 2016. Hence, it confirmed that the application of technical WMT procedures may increase precipitation rates and reduce the number of hot spots in Bengkalis.

1. Introduction

The peat fire disasters have been regularly occurred in the Riau Province, Sumatra, Indonesia. In the dry season, the peatlands will become dry and flammable. Peat contains fuel in the form of plant residue. Hence, small fires and smouldering may penetrate below the soil surface, burning peatlands slowly and it was hard to detect, thus causing thick smoke hazards. The smouldering in the peatland areas is also difficult to extinguish so it can be last for weeks [1]. The forest fires have negative impacts on the social and economic environment for Riau province and the regional areas of Indonesia, Malaysia, and Singapore. It was calculated that more than 1.600 of flight schedules were canceled from and to Sumatra during the period of August-October 2015. This affected to economic loss about US$8 million or Rp109 billion for airline industry [2, 3]. The impacts on the public health were even worst as there were rising cases of acute respiratory infection diseases (ISPA) more than 10 folds (normally 6000 cases per month) became 61.017 cases in September 2017 [4].

However, a large number of fire-fighting efforts were conducted in order to extinguish these wild fire trough water spray by the fire brigades from the land surface, and water bombs through the helicopters and airplanes from the sky, these efforts have been considered yield little impacts in reducing the large scale of the forest fire cases. Hence, there is a need to establish a robust precautions effort to mitigate peat forest fires before they occur. Several methods of forest fires prevention have been identified such water spray, water bombing and this study concern in the role of weather modification technology (WMT) [5].

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This paper considered the application of weather modification technology is as important approach in mitigating the forest fire disasters. According to T.P. DeFelice, 2005. He stated that the WMT might potentially give positive contribution in alleviating weather disasters such as severe smog hazards caused by the forest fire events and water resource deficiency caused by long dry season periods [6,7].

The WMT is highlighted as a human effort in modifying the existing weather conditions with a specific purpose in order to yield the desired weather conditions for example increasing the intensity of rainfall in a particular location (rain enhancement) otherwise decreasing rainfall intensity (rain reduction) in another one to minimize natural disasters caused by the climate change and weather conditions by utilizing weather parameters [8, 9, 13]

The state-of-the-art weather modification technologies have been applied toward mitigating the effects of peat fires in Indonesia, USA, Australia, and Thailand [5, 9]. The WMT activity is basically based on the effort in manipulating the existing natural conditions so that the concentration of smog hazards in the atmosphere can be reduced. This activity may have a positive impact on the atmospheric dynamics. This effect may include an improvement of precipitation rates consequently extinguish wild fires [6, 10, 11].

The role of WMT in mitigating of the forest fire disaster has been regulated in the Presidential Instruction of the Republic of Indonesia (RI) Number 16 the year 2011 concerning the Improvement of Forest and Land Fire Control in Indonesia. The President of RI since 2011 has instructed the Minister of Research and Technology to mitigate the forest and land fire disasters in Indonesia by conducting artificial rain-making technology (WMT) [12].

2. Literature Review

The terminology of weather Modification Technology (WMT) is defined as a human interventions and efforts in the control of water resources in the atmosphere to increase or decrease rainfall rates in a certain area in order to minimize the natural disasters caused by the climate and weather change [6, 8].

2.1. Cloud Seeding Mechanism.

The air bubbles constantly formed by the sea foam may cause the water particles to rise up to the sky. These particles called aerosols serve as water traps and then form water droplets. Furthermore, this aerosol rises into the atmosphere, and when a large amount of air is lifted to a higher layer, it will cool down and then condense. A collection of water droplets resulting from moisture in the condensing air is called as a cloud [5, 9].

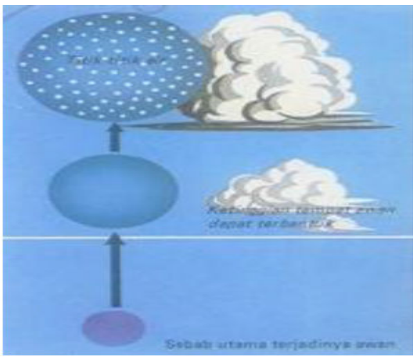


Figure 1. Condensation of clouds

At a certain level, the aerosol particles (0.01-0.01 micron) flying in the air will serve as condensation nuclei that cause the water moisture to condense. The main source of condensation core is salt derived from the seawater around the word. Since they are hygroscopic particles, the particles have become liquid droplets, and the collections of many droplets may form the clouds. The water particles surrounding the salt crystals and dust particles thicken, so the particles become heavier from the air, starting to fall from the clouds in the form of rainfalls. The main objectives of cloud seeding are to accelerate the collision process and the coalescence of the particles in the cloud which is a condition of rain to fall [13, 14].

Typically, clouds used as a seeding object are Cumulus (Cu) clouds which contain abundant of water vapor and has the potential to cause rainfall. The WMT is conducted in the form of cloud seeding by using hygroscopic seeding materials such as kitchen salt or Sodium Chloride (NaCl), $CaCl_2$, and Urea.

a. Jumping Process Mechanism: This method aims to accelerate the process of rainfall production. Initially, stages are by observing the clouds which carry plenty of water vapor from the sea and are considered potentially to cause rainfall will be "intercepted" away from the target area. By using the aircraft, the clouds are seeded with the objective to accelerate rain fall process [8].
b. Competition Mechanism: Applied for ground-based clouding activities with the Ground Based Generator system. For this second method, the goal is to disrupt the physics process in the cloud for growing convective clouds, so that the rain can be shortened in duration and reduced in intensity [13].

2.2. The Roles of WMT in Reducing Forest Fire.

This technology takes advantage of the opportunities that exist in the existing natural weather conditions. For example, with the application of WMT, the existing energy available in nature can be utilized effectively and efficiently to extinguish fires. Such energies may include wind energy, solar radiation energy, and airborne moisture content (potential clouds) which are available in the sky [15].

It is acknowledged that the existing peat fires would not continue smouldering as long as the amount of rain drops sufficiently rewetting the peat land surface. Thus it subsequently extinguished the existing peat fire events. It is necessary that as long as the amount a potential cloud around the fire location sufficient, there would be adequate rain to fall. There are several terms for the presence of potential clouds around the location of forest fires e.g. the amount of moisture content in the air (the conditions of the air column or the degree of air extinction that can support the potential cloud to grow). However, it is no guarantee that the growing cloud will become potential, although the amount of moisture content is in considered high and stable [13]. The accumulation of smoke hazards caused by peat fires prevented the sun's radiation penetrate the soil surface. Hence, the process of ground surface heating would not occur. This affect to stabilize the air column condition which is not possible to develop aerosol, condensation nuclei, and potential cloud. The application of WMT is also may reduce the smoke hazard concentration and improve cloud development processes.

Weather Modification Technology has been applied in Riau during the period of 22 June 2013 on 9 July 2013 and it was continued in the period of 14 June to 6 November 2016. In 2013, the WMT deployed two Hercules C130 TNI AU and Cassa BPPT aircrafts to seed 71.4 tons of NaCl over the Riau area. Based on the BPPT WMT, 2013 report, the WMT might improve rainfall intensity since June 23, 2013, in the Riau region, thus reducing the number of hotspots and reducing smoke [16].

In 2016 the WMT processes were conducted for 2 months period, deploying 1 aircraft CASA 212 from the BPPT to seed hygroscopic particles (NaCl 1-100 micron (μ)) [5].

Figure 2. CASA 212 aircraft for seeding activities 2016

This study investigated the roles of weather modification technology (WMT) may play in mitigating the peat forest disaster in Bengkalis, Riau Province, Indonesia by increasing precipitation intensity.

3. Research Methodology

3.1 Research sites.
This research was conducted in Riau Province, especially in Bengkalis Regency, The location of research is presented in the following figure.

Figure 3. Research location

The Weather Modification Technology (WMT), and track seeding data were obtained from BPPT and Riau University collaboration team 2016. This study also deployed a portable Global Positioning System (GPS) to tracking and recording the aircraft movement during seeding WMT materials.

The TRMM (Tropical Rainfall Measuring Mission) satellite, which was joint operating between NASA and the Japan Aerospace Exploration Agency was dedicated to monitoring and studying the tropical rainfall conditions along the equator were used to obtain Bengkalis precipitation data [17, 18]. The TRMM has been operated with 16 x passing orbit per day (92 minutes per orbit) with a resolution of 5.2 km. The remote sensing images could be obtained from the FileZilla application connected to the TRMM satellite. The precipitation recorded data were collected in this research in the period of July 15, 2016, until October 6, 2016.

3.2 Determining the Grid of Riau Province.
In determining Riau province grid done by using ArcMap version 10.3 software. The grid is used to determine the coordinates of the research area.

3.3 Rainfall Data.
In this study precipitation or rain, datasets were obtained from the satellite (Tropical Rainfall Measuring Mission) TRMM the Japan Aerospace Exploration Agency (JAXA). The TRMM satellite has been joint operated between JAXA and NASA and for monitoring and studying the tropical rainfall conditions along the equator (Figure 4).

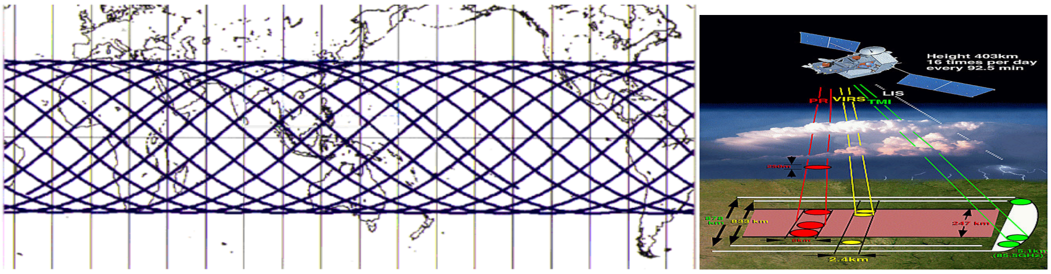


Figure 4. Tropical Rainfall Measuring Mission (TRM) orbit

Rainfall data is downloaded for three years from 2014 until 2016. The TRMM precipitation dataset has been considered as the space standard for measuring rainfall or precipitation rate [17, 18]. The rainfall data obtained in the form of rainfall hourly. FileZilla software was used to download the data. GrAds and Command Prompt software was used to analyze the data.

3.4 Hotspot Data.

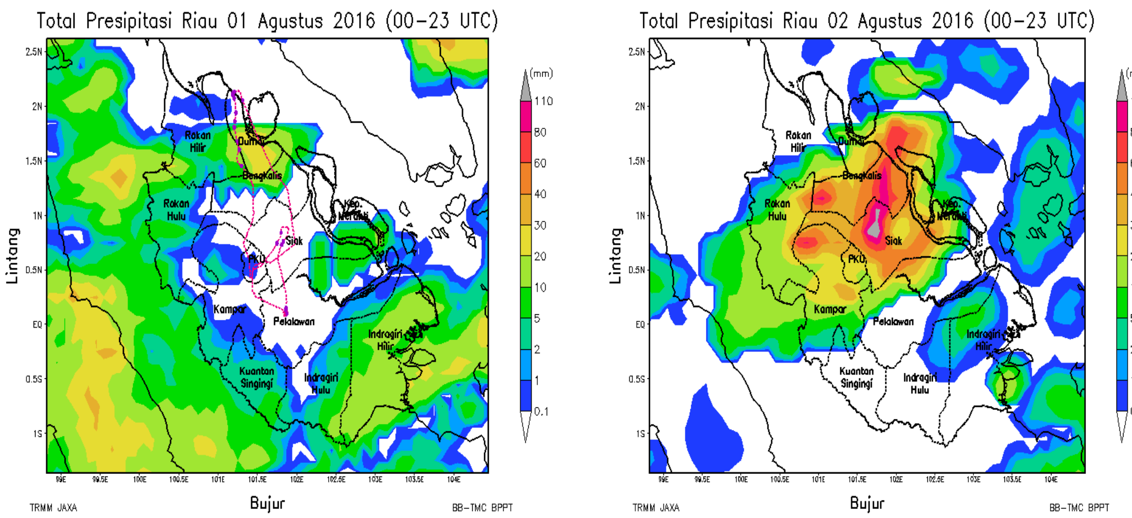
This research uses hotspot data for three years from 2014 until 2016 which were obtained from www.fires.forestwatch.com.

4. Results and Discussion

4.1 Weather Modification Technology Activities (WMT) and Its Impact.

The weather modification technology (WMT) was implemented in Riau province from July 15, 2016, to October 5, 2016. Here is an example of the impact distribution of rainfall rates along with the flight route and the seeding location on August 1, 2016 (Figure 5a).

The Figure 5a shows that there was no precipitation around Pekanbaru, Siak and Bengkalis area (white color zone). Then at August 1, 2016, WMT was conducted using CASA 212 aircraft. The flight routes were drawn in red line. On August 2, 2016 there was rainfall within the area Riau encompassing Siak, Bengkalis, Rokan Hulu and some parts of Pelalawan (Figure 5b).



(5a) **(5b)**

Figure 5a, 5b. The impact of rain distribution from the seeding process from 01 to 02 August 2016, in Riau Indonesia

There are 3 cases were evaluated in this study. This study evaluated the effect of weather modification technology (WMT) in an increase of precipitation rates [19, 20]. Based on the historical data an increase in the precipitation rates may reduce the peat fire events in Indonesia [13].

4.2 Case 1 Bengkalis 2014.

The significant number of hotspots were identified on February 23, 2014 with 534 hotspots. There was no rainfall for more than 10 days. During the period of March 5, 2014, to July 24, 2014, the Government conducted weather modification technology (WMT). On March 28, 2014, the number of hotspots decreased along with the rainfall occurrences. The number of hotspots decreased to 45 points with rainfall of 1.492 mm in that date. Until the end of the WMT period of 24 July 2014, the number of hotspots continued to decrease along with an increasing of rainfall rates gradually. Figure 3 shows the fluctuation between the numbers of hotspots with the rainfall intensity in Bengkalis District in 2014 (Figure 6).

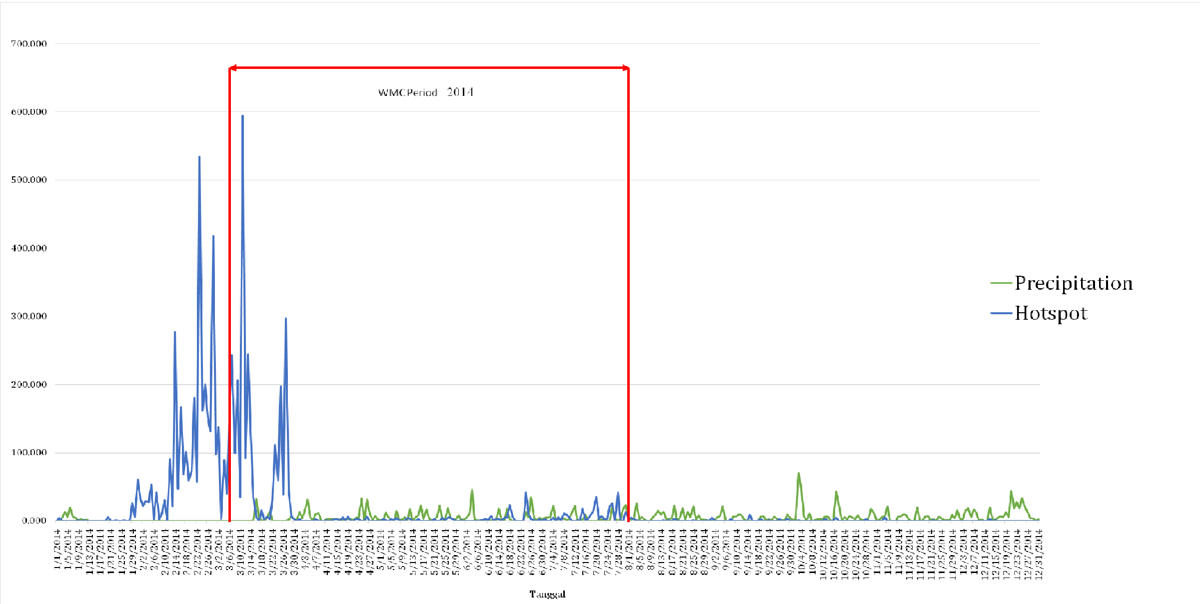


Figure 6. The comparison between the numbers of hotspots with the rainfall intensity in Bengkalis Regency 2014

4.3 Case 2 Bengkalis 2015.

At the beginning of 2015, it was detected as many as 86 hotspots occurred on March 14, 2015. The rainfall rate was recorded 0 mm. Then WMT program (under BPPT) was conducted at the mid of April 2015. As the results on April 23, 2015, the number of hotspots became 0 with the rainfall intensity of 19.59 mm. The hotspots decrease up to April 31, 2015. Then, the WMT was terminated on May 2017 as there was no more hotspots recorded.

Then WMT program was re-continued on July 2017. The number of hotspots on July 11, 2015, were recorded as many as 94 hotspots with the rainfall intensity of 0 mm. On August 2, 2015, the number of hotspots began to decrease significantly to 0 hotspots with the rainfall intensity of 38.071 mm. Hence, the number of hotspots decreased along with an increasing of rainfall intensity until the end of the WMT period of 20 November 2015 (Figure 7).

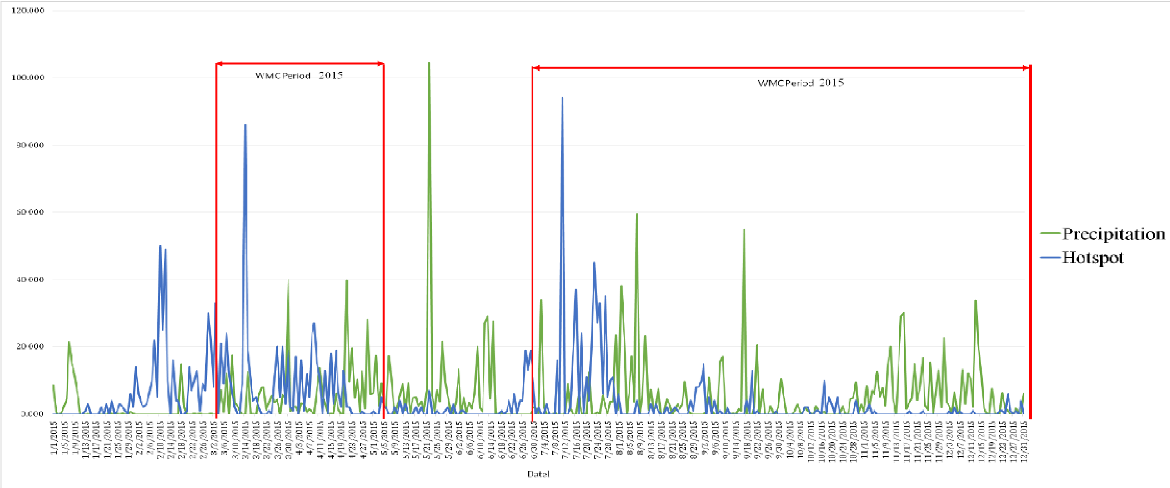


Figure 7. The comparison between the numbers of hotspots with rain intensity in Bengkalis Regency 2015

The figure 7 shows that during 2 periods of WMT (red lines) the number of hotspots tends to decline, and the rain intensity tends to increase.

4.4 Case 3 Bengkalis, 2016.

During the period of February 12 to 25, 2016 there was no rainfall events recorded and it caused the number of hotspots increased to become 17 occurrences. The number of hotspots tends to fluctuating up to March 21, 2016. Then the WMT program was conducted from June 15, 2016, to October 4, 2016. It was reported that on August 6, 2016, the hotspots was not detected due to high rainfall intensity. However, on August 19, 2016 until August 29, 2016 WMT process had to be halted because of there was no an available aircraft to conduct the seeding processes. During this period there was an increase of the number of hotspots up to 25 because there was no rainfall. After August 29, 2016 the WMT program was restarted again and the rain intensity rate increased, then as the consequences the number of hotspots decreased to 0 (Figure 8).

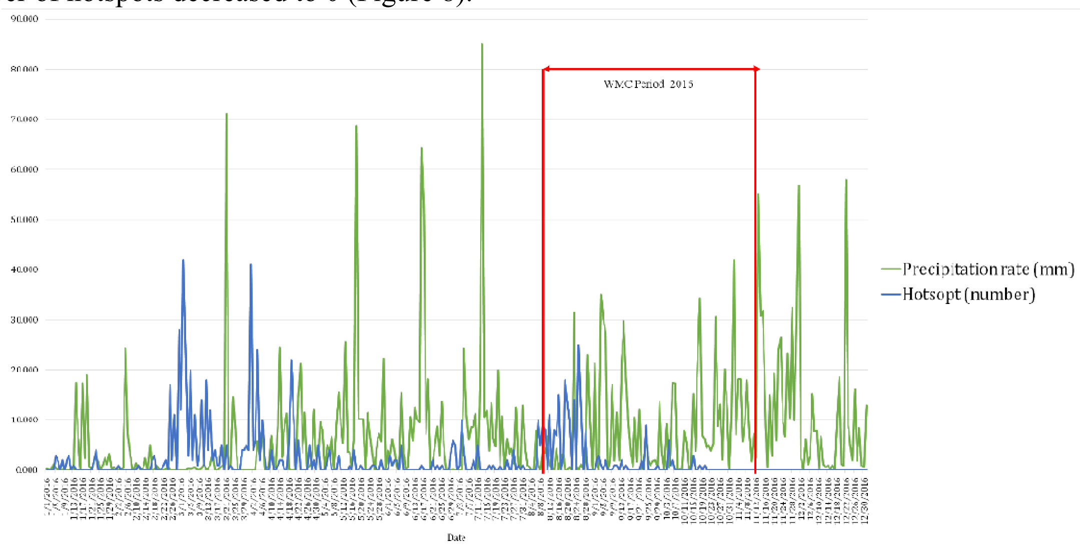


Figure 8. The comparison between the numbers of hotspots with rain intensity in Bengkalis Regency 2016

It was summarized that, the fluctuation of precipitation rates at the periods of 14 July to 6 October 2014, 2015 and 2016 in Bengkalis, Riau Province, has very strong correlation with the number of hotspots (-97.45 %), and the determination coefficient = 94.97% (Figure 9). There was 94.97% of the rainfall in Bengkalis affected to reduce the number hotspots, and 5.03% affected by other variables.

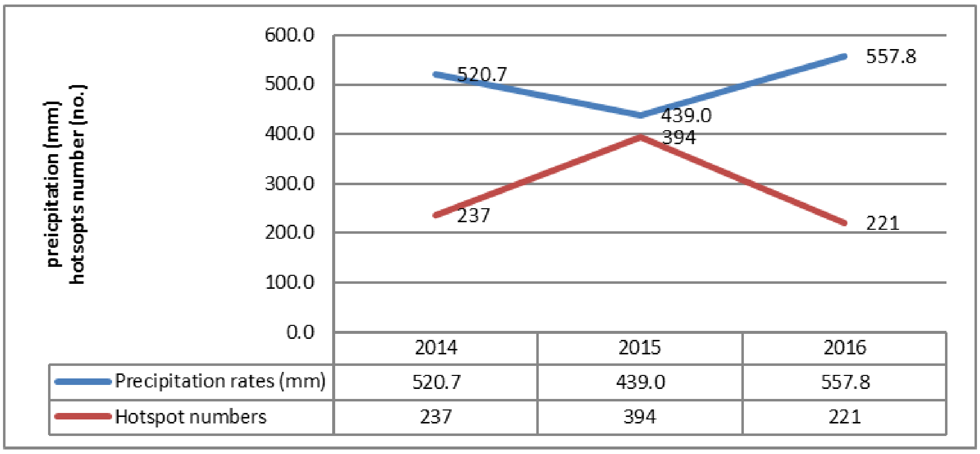


Figure 9. The precipitation rates vs the number of hotspots at the period of WMT of 14 July- 6 October 2016 in Bengkalis, Riau Province.

There was a strong correlation between the precipitation rates with the number of hotspots (adversely) at the peatland of Bengkalis. Hence, it was confirmed that the roles of WMC in improving precipitation rates have proved in reducing peatland fires in Bengkalis 2014-2016.

5. Conclusion

The result shows that weather modification technology (WMT) may enhance precipitation rates, thus this rain wetted the peat soil in Bengkalis, Indonesia thus as consequences the number of hotspots reduced significantly during the period of 2014, 2015 and 2015. It is recommended that this method can be used in mitigating peatland fire disasters in Indonesia.

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