



Application of Weather Modification Technology for Wetting Peatlands as a Mitigation Measure for Forest and Land Fires in South Kalimantan Province

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ABSTRACT

Weather Modification Operation (WMO) was conducted in South Kalimantan Province from July 29 to August 9, 2024, to support the wetting of peatland as a measure to mitigate forest and land fires. (karhutla). This operation was carried out by inserting superfine powder NaCl seeding material, which was sown into the clouds using the TNI AU's Casa 212-200 aircraft. Global and local weather factors were taken into account in determining the timing and location of seeding. El Niño and Indian Ocean Dipole (IOD) factors that were in the neutral phase as well as warm sea surface temperatures (+0.5°C to +2.0°C) around the waters of South Kalimantan contributed to the success of this operation. In the implementation of OMC, analysis of air humidity in the 925 to 500 mb layer showed the potential for convective cloud growth in most of the target areas, although humidity decreased on several days in certain layers. The implementation of the operation successfully increased rainfall in the target area, with rain intensity varying between 0 to 40 mm per day during the OMC period, resulting in significant wetting of peatland and an increase in groundwater table height (TMAT) at critical locations. The contribution of OMC successfully reduced the risk of forest and land fires by decreasing the number of hotspots in the priority peatland areas of South Kalimantan. In line with the Indonesian government's climate change mitigation strategy, we expect the long-term impact of this activity to reduce the intensity of forest and land fires and carbon emissions from peatlands in this area.

INTRODUCTION

Forest and land fires (karhutla) are one of the most frequent hydrometeorological disasters in Indonesia (Prayoga et al., 2021), especially in areas with peatlands such as Kalimantan and Sumatra. The karhutla phenomenon is further exacerbated by climate change, especially when the El Niño climate anomaly occurs, which causes long dry seasons, thus increasing the risk of fires in peatlands (Gaveau et al., 2014). This condition has encouraged various government agencies, including the Meteorology, Climatology, and Geophysics Agency (BMKG) and the Peat and Mangrove Restoration Agency (BRGM), to develop effective mitigation efforts in preventing and controlling fires, one of which is through Weather Modification Operations (OMC) (Sandhyavitri et al., 2018).

OMC is a weather intervention method that involves seeding superfine NaCl powder into clouds to enhance rainfall potential, with the goal of wetting peatlands to maintain soil moisture (Sutikno et al., 2020). Since its introduction in 1977, weather modification has become one of the government's main methods for preventing and reducing the impact of forest and land fires in Indonesia. In this mitigation effort, the government is not only focusing on extinguishing fires but also on rewetting peatlands as a preventive measure to prevent these areas from easily catching fire. In 2024, BRGM, in collaboration with BMKG, will implement OMC in South Kalimantan as part of the peatland rewetting program to reduce the risk of forest and land fires. Based on weather analysis from BMKG, dry conditions due to the influence of El Niño are expected to occur throughout the period from July to September, with a high risk of fires in peatlands in South Kalimantan. Therefore, we view OMC as the ideal solution to enhance soil moisture and mitigate the risk of forest and land fires by wetting the peatlands.

The point of this study is to look at how well OMC implementation works at increasing rainfall and keeping the soil moist in the peatland areas of South Kalimantan. It will also look at how it works at lowering the number of hotspots, which is a sign of successful forest and land fire prevention. We expect the results of this study to enhance our understanding of weather modification's effectiveness in mitigating forest fire disasters and establish a scientific foundation for future disaster mitigation policies.

THEORETICAL REVIEW

New Paradigm of Utilization of Weather Modification Technology in Forest and Land Fire Disaster Management Efforts in Indonesia

Weather Modification Technology (TMC) play a crucial role in mitigating forest and land fires (karhutla) in Indonesia. Based on the basic concept of cloud seeding, this technology is able to increase the efficiency of rain formation in areas affected by fires. TMC operates by intervening in clouds using seeding materials, which accelerate the collision process between particles, thereby increasing the likelihood of rain. This approach is particularly useful in situations of thick smoke, which frequently occur in fire areas, as smoke hinders the natural cloud formation process by competing with cloud particles for limited water vapor. Along with the development of technology and mitigation policies, the implementation of OMC in Indonesia has now become part of a permanent and

integrated solution in disaster management. We hope that this approach will enable TMC to sustainably reduce the impact of Karhutla in the future and enhance Indonesia's climate resilience. (Harsoyo et al., 2022)

The Effect of Rainfall on the Decrease in Hotspots in Indonesia in 2019-2020

Forest and land fires (karhutla) are an annual problem in Indonesia, especially in areas with a lot of land conversion, such as Sumatra and Kalimantan. Rainfall plays an important role in determining the frequency and intensity of hotspots that indicate potential fires. Research from 2019-2020 indicates that an increase in hotspots often follows low rainfall, particularly during the dry season between July and October. This study confirms a negative correlation, with a P-value below 0.05, between rainfall and the number of hotspots, particularly in South Kalimantan. This implies a direct relationship between increased rainfall and a decrease in hotspots. This correlation emphasizes that rainfall management can be an effective solution to reduce the risk of forest and land fires, especially in dry conditions or during the dry season. (Saharjo et al., 2022).

Evaluation of the Value of Additional Rainfall from the Implementation of Weather Modification Technology in Efforts to Handle Forest and Land Fire Disasters in Indonesia

Indonesia has long applied Weather Modification Technology (TMC) to mitigate forest and land fires (karhutla), particularly in vulnerable areas like Riau, Kalimantan, and Sumatra. TMC works by seeding clouds to increase rainfall intensity, which is effective in reducing the risk of fire and maintaining peatland humidity. The results of the implementation of TMC show a significant increase in rainfall in various climate conditions, including during the wet climate phenomenon (La Nina), which generally provides more optimal results than dry climate conditions (El Nino). This study tested the effectiveness of TMC through two evaluation methods, namely Target Only and Target Control. The Target Only method calculates the increase in rainfall by comparing the actual rainfall in the target area during the TMC period with the historical rainfall in the same period. Meanwhile, Target Control involves a comparison from a control area that is not affected by cloud seeding to ensure that the increase in rainfall in the target area is truly the result of TMC. (Harsoyo et al., 2023).

Correlation Analysis of Hotspot Density with Rainfall in Sumatra and Kalimantan Islands

Forest and land fires, also known as karhutlas, pose a serious problem in Indonesia, particularly on the islands of Sumatra and Kalimantan. Various factors, including extreme dry seasons and human activities like land clearing by burning, contribute to these fires. This study aims to understand the relationship between the density of hotspots and rainfall in an effort to mitigate forest and land fires on the two islands. The study found a negative correlation between the number of hotspots and monthly rainfall, with a correlation value of $R = 0.307$. This indicates that as rainfall increases, the number of hotspots tends to decrease,

and conversely, when rainfall is low, the number of hotspots tends to increase. This pattern is consistent every year and can serve as an indicator for preparing fire mitigation strategies, particularly through the application of Weather Modification Technology (TMC) in the dry season before the hotspots reach their peak. (Prayoga et al., 2017).

METHODOLOGY

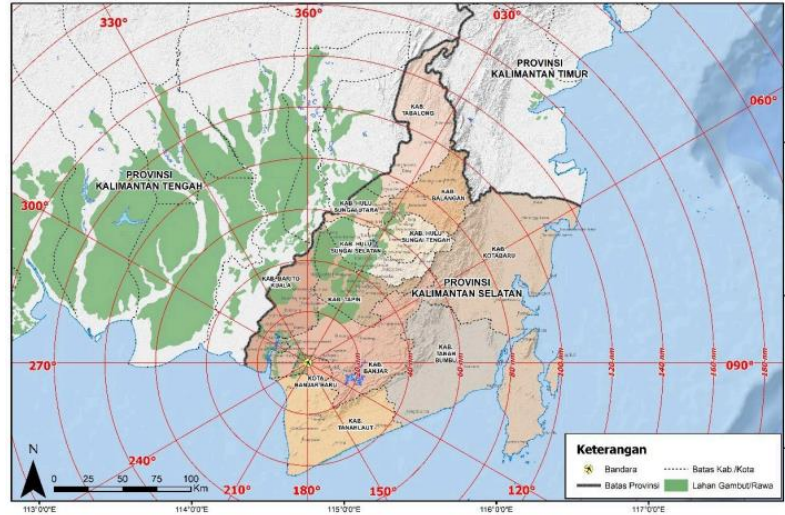


Figure 1. OMC South Kalimantan Work Map 2024 (Source: BMKG, 2024)

The location of this research is in the South Kalimantan region, specifically in areas with a high risk of forest and land fires. To obtain accurate results on the effectiveness of TMC in significantly increasing rainfall in fire-affected areas, this research combines a quantitative descriptive method with spatial and temporal analysis. Additionally, the research employs the Target Only Method, which utilizes historical average data to provide comparative information. We calculate the influence of seeding and the magnitude of rainfall increase by comparing the rainfall during the seeding period in the target area with the historical rainfall for the same period in that area. The calculation of rainfall increase according to this method is based on the following equation :

$$R = \frac{CH_a - CH_s}{CH_s} \times 100\%$$

dengan,

R = Rainfall Increase Rate (%)

CH_a = The Actual Rainfall Amount in the target area during the OMC Period (mm)

CH_s = Average historical rainfall in the target area (mm)

RESULTS

The implementation of OMC in South Kalimantan Province, which took place during the period of July 29–August 9, 2024, has been carried out for 12 days of activities. During this period, there were 16 (sixteen) flight sorties with Casa 212-200 A-2104 aircraft with a total flight time of 29 hours 35 minutes (twenty-nine hours thirty-five minutes) and used up 12,800 kg (twelve thousand eight hundred kilograms) of NaCl (Table 1).

Table 1. Recapitulation of OMC flight activities in South Kalimantan Province in 2024

Aircraft	OMC Flight Activities	
CASA 212-200 A-2104 (July 29–August 9, 2024)	Number of Sorties	16
	Flight hours	29 Hours 35 Minutes
	Seeding Material	12.800 kg
	Activity Day	12 Days

This activity focuses cloud seeding flights on wetting the land, particularly peat, to prevent forest and land fires in South Kalimantan Province. Therefore, cloud seeding flights are more focused on reaching and seeding potential clouds in the western to northern areas of South Kalimantan Province, such as Banjarbaru City, Banjar Regency, Barito Kuala Regency, Tapin Regency, Hulu Sungai Selatan Regency, Hulu Sungai Tengah Regency, and Hulu Sungai Selatan Regency. The OMC activity records the aircraft flight path during a cloud seeding mission (seeding track), as shown in Figure 2.

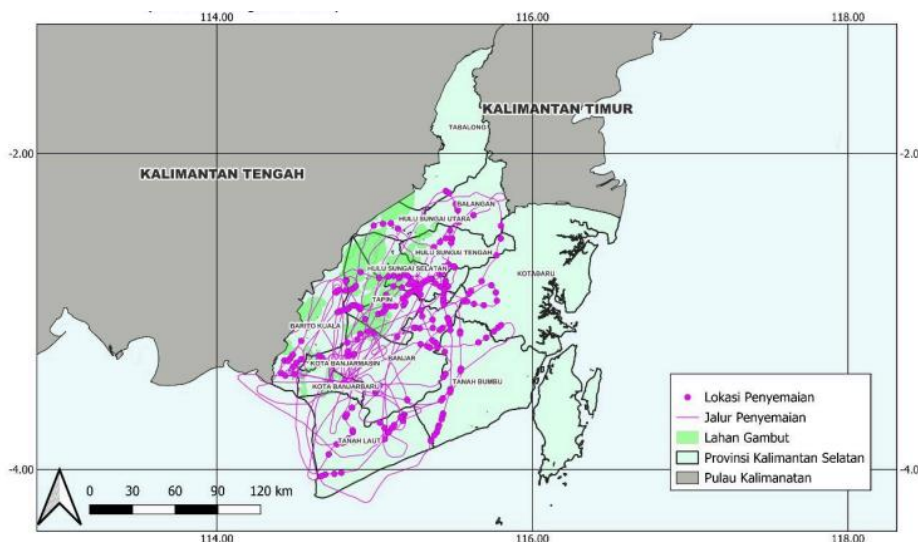


Figure 2. OMC activity records aircraft flight paths during cloud seeding missions. (Source: BMKG, 2024)

Weather Modication Operation Results

The reported activity results include information on rainfall in the South Kalimantan Province; additional rainfall due to OMC intervention; peat

groundwater levels; and hotspots. BMKG sourced the rainfall information during the activity, while JAXA's GSMaP (Global Satellite Mapping of Precipitation) Satellite provided the data. We obtained Peat Groundwater Level (TMAT) information from BRGM. We also monitor the number of hotspots in South Kalimantan Province daily. KLHK manages SIPONGI, which sources hotspot data using the MODIS (Terra & Aqua) satellite.

Temporal Rainfall

Various sources provide information on rainfall events during OMC activities. During cloud-seeding flights, flight scientists observe and record any rainfall events. Stakeholders and the public also provide information. In this case, we refer to the information from flight scientists and the public as qualitative rainfall event information. We also obtain rainfall information from BMKG rain gauges and rainfall data from the GSMaP satellite, which we refer to as quantitative rainfall. Nearly every day, OMC activities report information on rainfall events, whether from the aircraft cockpit during flights or from the command post. The BMKG rain gauge station, which measures rainfall quantitatively, has 36 gauge stations spread across the South Kalimantan Province. During the activity period from July 29 to August 9, 2024, the BMKG rain gauge recorded rainfall conditions in South Kalimantan Province that ranged from light to extreme intensity, with an average area value ranging from 0.1 mm/day to 31.6 mm/day. The highest rainfall with a very heavy rain category ever occurred at the AWS Maritim Kotabaru rain gauge with an intensity of 167.4 mm/day and at the AAWS SMPK Kotabaru rain gauge with an intensity of 126 mm/day, which occurred on August 6, 2024. Overall, the 37 gauge points spread out resulted in an accumulated rainfall in the South Kalimantan Province of 2,135.4 mm/12 days. Figure 3. presents the temporal (daily) rainfall conditions in the South Kalimantan Province from 29 July to 9 August 2024.

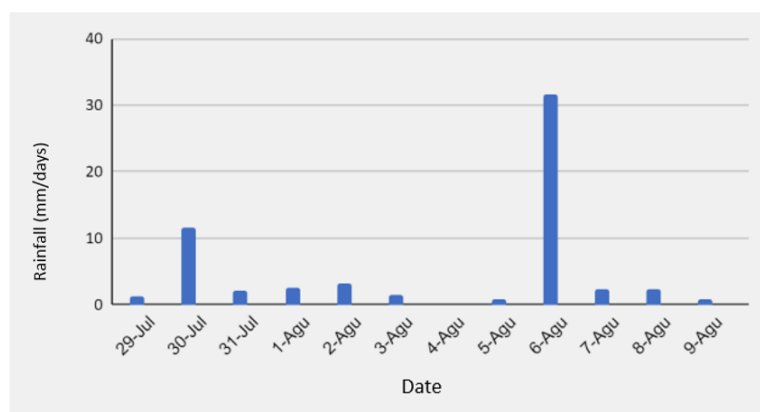


Chart 1. Average Rainfall for the OMC Period in South Kalimantan in 2024
(Source: BMKG, 2024)

Complementing the analysis of rainfall data from the rain gauges described above, rainfall analysis was also carried out using data from the JAXA GSMaP Satellite. The intensity of daily rainfall that occurred during the

implementation of OMC in the target areas in the form of peatlands (Barito Kuala Regency, Tapin Regency, Hulu Sungai Selatan Regency, Hulu Sungai Tengah Regency, Hulu Sungai Utara Regency and Balangan Regency) of South Kalimantan Province based on data from the JAXA GSMAp satellite is presented in chart 2. The actual rainfall in 2024 is depicted in the blue block, the actual previous year (2023) with a gray block and the historical average value with an orange line. From the figure, it can be seen that during the 10 days before the implementation of OMC in South Kalimantan Province (19 - 28 July 2024), the rainfall intensity was relatively lower compared to the historical average value and also the actual previous year. Furthermore, conditions began to improve during the implementation of OMC on July 29 - August 9, 2024, where the intensity of daily rainfall that occurred in several days was higher than the historical average and actual values of the previous year, especially on August 6, 2024. This was due to the influence of global / regional weather factors (Equatorial Rossby waves) passing through Kalimantan Island which significantly affected the growth of convective clouds and when OMC was carried out, it could increase the intensity of the resulting rain. So that it can be useful for wetting peatlands.

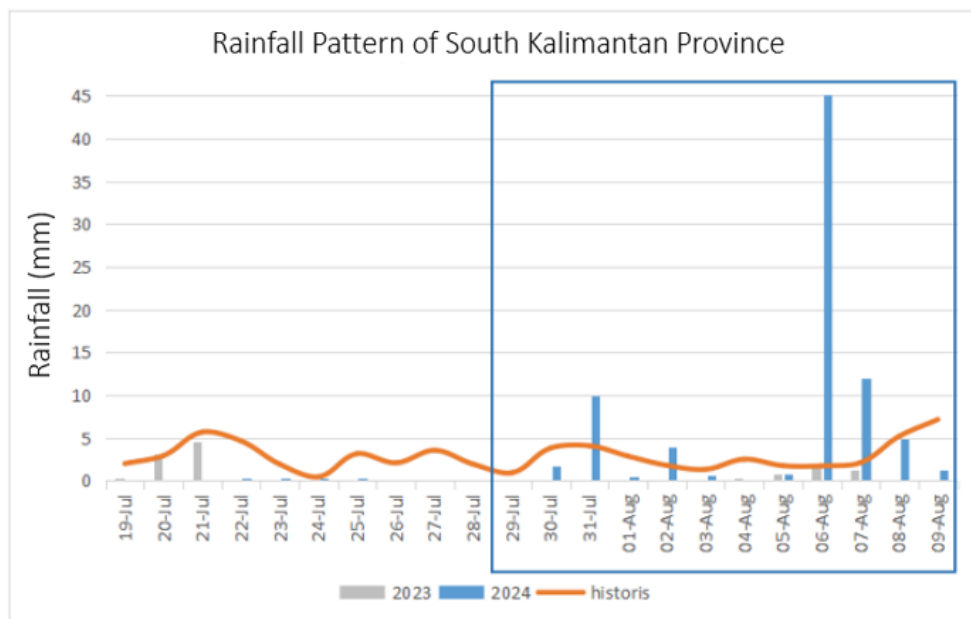


Chart 2. The South Kalimantan Province experienced regional rainfall from 29 July to 9 August 2024.

(Source: GSMAp-JAXA)

Spatial Rainfall

Spatial rainfall information is used to see the distribution of rainfall throughout the target area. In addition to the distribution of rainfall from the distribution of gauges spread across the South Kalimantan Province, spatial rainfall data was also taken from the GSMAp Jaxa satellite. The GSMAp Satellite data enables the detection of rainfall events in all locations, even those that are challenging for humans to access. The rainfall distribution map (isohyet) with

GSMaP rainfall for the period July 29 to August 9, 2024 in South Kalimantan Province is presented in figure 3. From the image, precipitation is evenly distributed throughout the South Kalimantan Province. Tanah Bumbu Regency recorded the highest rainfall intensity, ranging from 200-3350 mm/12 days, with some areas even surpassing 350 mm/12 days. In the seeding area, rainfall was observed to range from 20 to 350 mm/ 12 days. Spatially, the East to Southeast regions of South Kalimantan Province tend to get more rain than other areas.

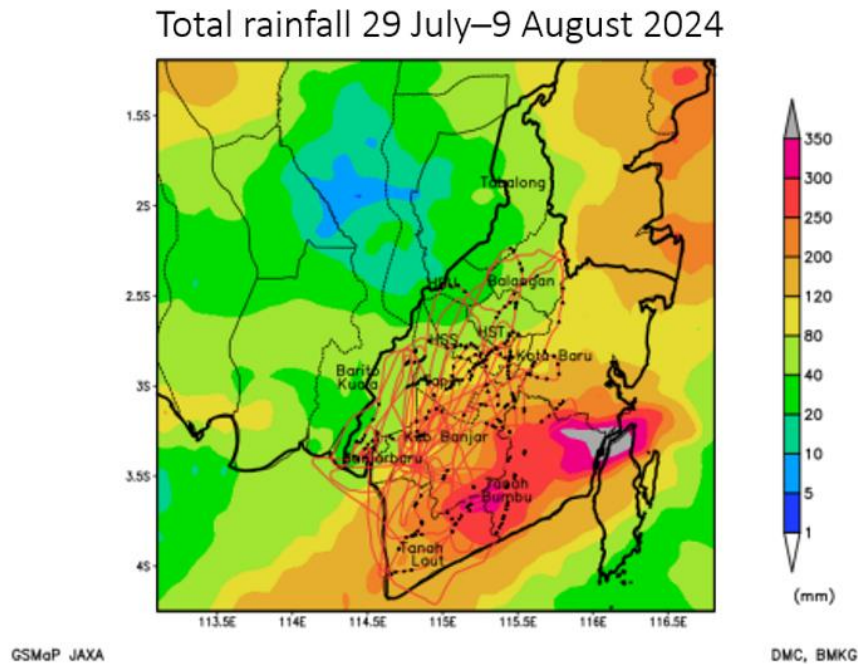


Figure 3. The distribution of accumulated rainfall in South Kalimantan Province spans from 29 July to 9 August 2024.

(Source: BMKG-diolah dari GSMaP-JAXA, 2024)

Spatial Rainfall

The volume of rainwater during the OMC implementation period in the South Kalimantan Province, which is the target area, is seen in Table 2. The volume of rainwater in a particular province is calculated based on the thickness of precipitation measured on the GSMaP satellite during the OMC implementation period multiplied by the area affected by the OMC seeding activity in the province.

Table 2. Total Volume of Rainwater Resulting from OMC Intervention

No	Date	Daily Total (million m ²)
1	July 29, 2024	0.14
2	July 30, 2024	2.15
3	July 31, 2024	0.94
4	August 1, 2024	1.10
5	August 2, 2024	1.46
6	August 3, 2024	0.62
7	August 4, 2024	No Flight
8	August 5, 2024	0.35
9	August 6, 2024	16.88
10	August 7, 2024	2.72
11	August 8, 2024	2.49
12	August 9, 2024	1.36
Total		30.22

(Source: BMKG-from GSMAp-JAXA, 2024)

The calculation results estimate that during the implementation period of OMC activities in South Kalimantan Province, the volume of rainwater around the seeding area will reach 30.22 million m³. We expect the volume of rain from OMC intervention to keep the peatland in the target area moist and wet, thereby suppressing the potential for hotspots and the spread of forest and land fires over a large area.

Additional Rainfall During OMC Implementation

The calculation of additional rainfall due to intervention from the implementation of OMC is calculated based on historical rainfall with actual rainfall at the time of OMC implementation using data from the JAXA GSMAp satellite. The historical rainfall taken is the year in a normal climate, namely 2008, 2012, 2013, 2014, 2017, 2018, and 2019. Table 5.2 below displays both historical and actual rainfall data.

Table 3. Historical and actual average accumulated rainfall values and percentage increase in rainfall from OMC results

Period	Rainfall Value (mm)		Percentage Increase in Rainfall
	Historical Rainfall	OMC Intervention Actual Rainfall (GSMAp)	
July 29 – August 9, 2024	42,44	80,74	85,87

(Source: BMKG-from GSMAp-JAXA, 2024)

Based on the above references, by comparing the same period between historical and actual, namely in the period of July 29-AAugust 9, 2024, it can be seen that:

- The average accumulated rainfall value in the South Kalimantan Province based on historical in normal climate years is 43.44 mm.
- The actual accumulated rainfall during the OMC period implemented in the South Kalimantan Province is 80.74 mm.
- Through historical comparison, there is an indication of additional rainfall due to the OMC intervention during July 29-August 9, 2024, which is 37.30 mm, or equivalent to an increase in rainfall of 85.87% from the historical average. Rain with a fairly high intensity reaching 45 mm/day occurred on August 6, 2024, due to the influence of global weather factors (equatorial Rossby waves) passing through the island of Kalimantan, which significantly affects the growth of convective clouds and when OMC is carried out, it can increase the intensity of the resulting rain. This makes the rain beneficial for soaking the dispersed peatlands. In general, the implementation of OMC in the South Kalimantan Province from 29 July to 9 August 2024 resulted in an increase in rainfall of 85.87%.

Hotspots

The Ministry of Environment and Forestry, through the SIPONGI website <https://sipongi.menlhk.go.id>, monitored the number of hotspots in South Kalimantan Province daily during the implementation period of OMC activities from July 29 to August 9, 2024. The MODIS (Terra & Aqua) satellite detected the number of hotspots during OMC activities with a confidence level of more than 80% (high confidence), indicating that there was only one hotspot in the South Kalimantan Province (Figure 5.5). On August 1, 2024, further verification of the hotspot location revealed that the mining area was the hotspot location with a confidence level of more than 80% (high confidence).

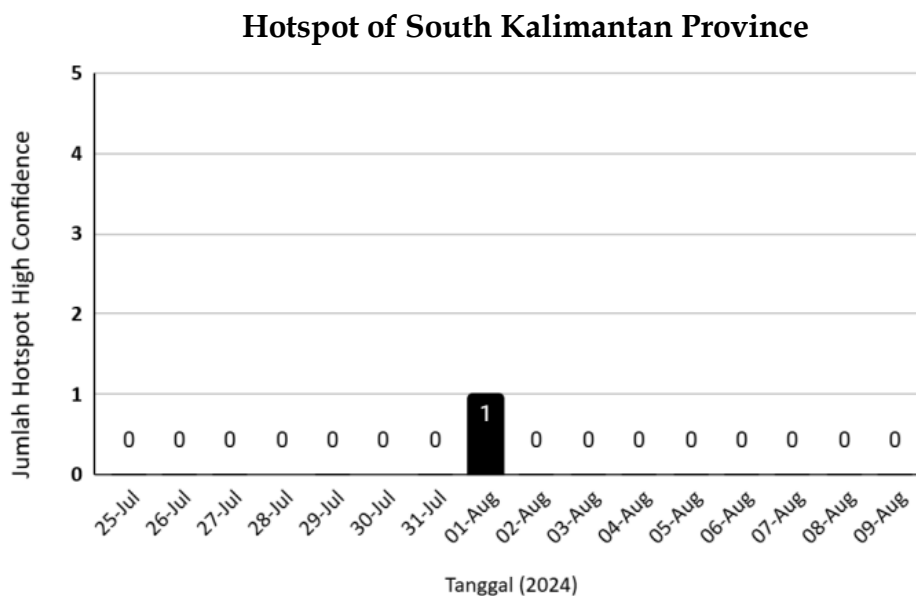


Chart 3. Daily hotspot monitoring with high confidence level in South Kalimantan Province during OMC implementation
(Sumber: SIPONGI-KLHK, 2024)

FURTHER STUDY

This study has successfully increased rainfall in the target area, but it has certain limitations, including atmospheric variability that may not always support optimal cloud seeding and the need for long-term monitoring of peatland moisture. We recommend further research to develop more effective methods for identifying atmospheric conditions, continuously monitor the impacts of OMC, explore more environmentally friendly seeding materials, and use AI models to predict priority target areas. We expect this approach to enhance the accuracy and sustainability of forest and land fire mitigation in Indonesia.

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