Evaluation the Effectiveness Implementation of the Weather Modification Technology for Mitigating Peatland Fires

Ari Sandhyavitri\textsuperscript{1a)}, Ilvi Rahmi\textsuperscript{1b)}, Heru Widodo\textsuperscript{2}, Rizki Ramadhan Husaini\textsuperscript{3}

\textsuperscript{1} Civil Engineering Department, University of Riau, Pekanbaru, Indonesia 28293
\textsuperscript{2} Weather Modification Technology Centre, Agency for the Assessment and Application of Technology, Indonesia
\textsuperscript{3} Civil Engineering Department, Universitas Abdurrahman Wahid, Pekanbaru, Indonesia 28293

\textsuperscript{a)} Corresponding author: ari.sandhyavitri@lecturer.unri.ac.id
\textsuperscript{b)} ilvi.rahmi@student.unri.ac.id
\textsuperscript{c)} fhwidodo@yahoo.com
\textsuperscript{d)} rizki.ramadhan@univrab.ac.id

\textbf{Abstract.} The objective of this article is to evaluate the effectiveness implementation of the weather modification technology (WMT) for mitigating peatland fire disasters in Riau Province, Indonesia. The implementation of this WMT in Indonesia has been relatively new and challenging as this cutting-edge technology may increase the precipitation rates and therefore, it may reduce the risk of peat fire hazards in the huge massive areas. The Riau province has experienced serious peatland fire disasters from the period of 2014 to 2016. The evaluation of WMT in this article was focused on four regions within Riau encompassing Indragiri Hilir regency, Meranti Island, Pelalawan, and Siak. The Tropical Rainfall Measuring Mission (TRMM) satellite data were used to calculate the precipitation rates. The method applied to evaluating the effectiveness of WMT was the Target Only Method (TOM). This method calculated the precipitation rates during the WMT period, which is compared to the historical precipitation data in a similar period. The total duration of a 3-year WMT implementation was 380 days, and the results were considered successful as an increase of precipitation rate (PCH) = 2.09 > 1.00. Hence, there was an increase in the average of precipitation rate during WMT period of 2014-2016 in Riau.

\textbf{Keywords:} weather modification technology (WMT), peat fires, precipitation, rainfall, evaluation, Riau.

1. Introduction

Peatland areas play a crucial role in maintaining the sustainability of biodiversity conservation and climate regulation, which would provide an important element in supporting human welfare [1,2]. However, currently peatlands are only covering 3\% of the land area on the world; the peatlands contain nearly 30 percent of the overall carbon storage on the earth. Peatland is also considered as the most efficient terrestrial ecosystem in storing carbon in the word [3]. Peatlands are fragile ecosystems, which were performed by the accumulation of dense wet plant material and carbon components, which prone to peat fire events during dry seasons. Once peatlands are drained for example for commercial palm oil industry or pulpwood plantations purposes, the dry peatland is at the risk of peatland fires. In fact, peat fire may release carbon into the atmosphere and causing smog hazard disasters, which is effecting to cause severe environmental and social disasters [4, 5]. Obviously, the peatland fire disasters have been experiencing very difficult to extinguish because of the peatland fires have
occurred below the surface area (smouldering) that can only be extinguished using a lot of water or in
the presence of rainfall [6].

The objective of this article is to evaluate the effectiveness application of the weather modification
technology (WMT) in increasing the precipitation rate for mitigation peatlands fire in Riau Province,
Indonesia in the period of 2014-2016. The peatlands have covered 56% of the total Riau land area.
During the period of 2014 and 2015, Riau experienced serious fire disasters occurrence cussed by the
dry weather conditions caused by the El Nino effect.
It was very challenging for extinguishing peatland fire disasters as the peat fires may generate smog
hazard disasters that were choking massive regions. Hence, the WMT is an important meteorological
technique for generating artificial precipitation for many kinds of purposes included for mitigating
peat fire natural disaster [6].

2. Methods
The WMT is a type of human interference for modifying the weather conditions by increasing or
reducing the perception rates in the designated areas [7, 8].
Currently, the application of Weather Modification Technology (WMT) has been one of the technical
solutions to ease the peatland fires in Indonesia [7].
The state-of-the-arts successful in the implementation of WMT for increasing precipitation rates have
been reviewed in several countries such as in USA, Australia, and Thailand. However, the evaluation
and publications related to the implementation of WMT for mitigating peat fires is limited [6, 7, 8],
thus this article may yield positive contribution to the body of knowledge in the area of peat fires risk
mitigation and control.

In this article, the terminology of peatland fires and peat fires are interchangeable as well as rain
and precipitation. However, for some experts, these terminologies may yield different meanings.

Weather Modification Technology (WMT) is a type of human effort in manipulating weather and
climate conditions intentionally in a designated area for specific purposes [7]. WMT activities are
generally implemented for addressing the major climate and weather disasters such as drought, forest
fires, and floods [8].

The WMT method has been conducting by performing clouds seeding utilizing various equipment
such as cloud seeding aircraft, rocket launchers, artillery and ground-based generator (GBG)
equipment (Figure 1). The WMT activities in Indonesia have been conducted utilizing aircraft, rocket
launchers, and GBG [7]. In Indonesia, the WMT has been applied since 1979 for various purposes,
such as for increasing precipitation rates in maintaining a number of lakes water level in Java, Sumatra
and Sulawesi Islands for sustaining electricity power supply during dry season condition. This WMT
has been also be implemented for mitigating forest fire and peat fire disaster occurrences [9].
The WMT is performed by mimicking the cloud development process in the sky through-out the cloud
seeding activities. A number of hygroscopic particles of size <10 microns (e.g. Sodium Chloride, NaCl),
was carried by a specific airplane (Figure 1a and 2) and the particles are intentionally injected
directly into the cloud so that the process of rainfall in the cloud are expected to occur (Figure 3).
Otherwise, the hygroscopic particles are also released by utilizing Ground Particle Generator
equipment (Figure 1b)
Figure 1. (1a) CASA 212 aircraft for cloud seeding activities di Provinces Riau, 2016; and (1b) Ground particle generator in Jakarta, 2014.

Figure 2. Seeding NaCl processes on the clouds

Figure 3 illustrated that the release of the hygroscopic particles is conducted under the cloud base or on the cloud surface within the updraft area. The cloud seeding activities may also speed up the process of collision and coalescence of water droplets in the cloud for accelerating rainfall processes.

Figure 3. Cloud seeding process
Then at the high levels of the atmosphere, the water vapor in the humid air condenses on condensation-core into tiny cloud particles. Naturally, core-condensation is abundant in the atmosphere. Through the process of the cloud development and supported by the continuous entrainment of the water vapor from the environment below the cloud base, the clouds grow to become larger shapes, and perform heavy rain clouds; ultimately, these cause rain to fall.

2.1 Why Weather Modification Technology
The advantages of implementing WMT compared to other technologies in mitigating and extinguishing the peatland fires may be drawn as the following arguments:

- There has no well-known technology incapable of extinguishing peatland fires in wide escalation areas, except by “rainfall” which can be triggered by the application of WMT.
- In the thick smoke condition (affected by the peat fire events), the smoke may block the sunrays from entering the earth's surface. As a result, the earth's surface temperature is not warm enough to maintain the stability of the vertical profile of air temperature to raise up water moisture for performing clouds. Thus the convection activity would not be performed so that the condensation process. As the consequences, the rainfall (precipitation process) could not be well-performed. The WMT is able to develop the clouds formations from the initial cloud development phase to maturity one by sprinkling large amount of hygroscopic seedlings (UGN: Ultra Giant Nuclei, 10-50 microns such as Sodium Chloride). The presence of this seeding material may increase the efficiency of collision and coalescence in the cloud causing the rain to fall.

2.2 Study area
This study was carried out in Riau Province, Indonesia. (Figure 4). According to Global Forest Watch, 2020 report in 2001 this Province had 3.67 Mha of primary forest including peatland area, extending over 41% of its land area. After 18 years, in 2019, this province had lost 24.4 Kha of its primary forest including peatland area caused by the fires and commercial industrial purposes (this loss was equivalent to CO₂ emissions 11.6 Mt). Hence it is important to mitigate and control forest fires to conserve the forest as well as peatland areas using WMT approach.

2.3 Data
2.3.1 Hotspots. The data of the peat fire occurrences in Riau were calculated using hotspot data (80% accuracy) which were downloaded from www.fires.globalforeswatch.com in the shapefile format and figure (Figure 5).

In general, based on the Global Forest Watch 2020 data, it was identified that between 30th December 2013 and 1st January 2017 Riau experienced a total of 175,061 Visible Infrared Imaging Radiometer Suite (VIIRS) fire alert events (https://www.globalforestwatch.org). The highest fire alerts (hot spot) occur in the period of February, 2014 (4,705 hot spots), May 2014, October 2014, May 2015, August, 2015, March 2016, and August 2016 (Figure 5).
Figure 5. Visible infrared Imaging Radiometer Suite (VIIRS) fire alert (Hot Spots) in Riau, 2014-2016

This article also illustrated that a case study in Meranti Island. Table 1 describes the hotspot data of Meranti Island Regency in 2014, 2015 and 2016. The number of peat fire occurrences within period of 2014, 2015 and 2016 for Meranti is presented in Figure 6.

Table 1. The number of hotspots in Meranti Island Regency from 2014 to 2016

| Year | Meranti Island |
|------|---------------|
| 2014 | 2921          |
| 2015 | 321           |
| 2016 | 320           |

Source: www.fires.globalforestwatch.com

2.3.2 Precipitation rate data. The precipitation data in the period of 2014-2016 were obtained from the Tropical Rainfall Measuring Mission (TRMM) satellite. The TRMM has been operated by the National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA). This satellite was operated to gather the tropical rainfall data within the equator belt with a resolution of 5.2 km (NASA, 2017, and NASA, 2016). The TRMM data were downloaded using the FileZilla application which was connected to the TRMM satellite data. The precipitation
recorded data were collected in this research in the period of July 15, 2016, until October 6, 2016. The TRMM rainfall data has been widely used for many kind applications, such as for hydrological modeling [10-12]. The data was downloaded using free open source platform FTP of software FileZilla Client.

2.3.3 Evaluation of Weather Modification Technology. This article evaluated the implementation of WMT in mitigating the peat fire disasters. Based on some research studies it was evaluated that the application of WMT has positively contributed to mitigating severe smog hazards caused by forest fire events and water resource deficiency in the dry season conditions.

The evaluation of the successful implementation of WMT was conducted by using Target Only Method (TOM) because the method is relatively simple to perform by comparing the amount of precipitation rate during the implementation of the weather modification technology in a certain period with the historical data of the rainfall rate in the similar conservative period. The magnitude of the increase in rainfall is expressed by the equation (Hess, 1974)

\[
PCH = \left(\frac{R_{Tp}}{R_{Th}}\right) \times 100\%
\]

Where: PCH = an increase of precipitation rate (%),

\(R_{Tp}\) = precipitation rate in the targeted area during the WMT period, and

\(R_{Th}\) = historical precipitation data in a targeted area in the similar period.
If PCH > 1 the implementation of WMT is considered success and vice-versa.

3. Results and discussion
This article calculated the precipitation rates for 4 areas in Riau Provinces during 2014, 2015 and 2016 periods including Indragiri Hilir regency, Meranti, Pelalawan, and Siak. The analysis detail about WMT Condition only in 2014. The remaining WMT condition in 2015-2016 are presented briefly.
Based on the data obtained from the Agency for the Assessment and Application of Technology (BPPT, 2014-2016), there were recorded 60 WMT events were deployed for four regencies in Riau during 3 years period of 2014-2016 (Table 2).

| Year 2014 (Total 144 days) | Year 2015 (Total 152 days) | Year 2016 (Total 84 days) |
|---------------------------|---------------------------|---------------------------|
| 5 March-31 March | 2 March-31 March | 15 July-31 July |
| April | April | August |
| May | 22 June-30 July | September |
| June | August | 1 October-6 October |
| 1 July-24 July | September | 1 November-20 November |

3.1 Precipitation Rate 2014-2016
During the implementation of the WMT in 2014, it was identified that 143 flight sorties were conducted for mitigating peatland fires in Riau with 293 flight hours and 31 minutes carried 457,040 kg of seeding agents (NaCl). The total duration of WMT was 144 days (Table 2).
Although in May and June 2014, there was detected an increase in the sea surface temperature anomaly (SST) values in the El Nino area within the Pacific Ocean region near the equator belt, it still showed that the El-Nino Southern Oscillation (ENSO) conditions were relatively neutral and the dry weather condition in Indonesia could be predicted.
The dry season in Riau was indicated by a very low humidity parameter, which occurred in the second week of March, the second week of April, the third week of June, and the fourth week of July 2014. Extreme weather with temperatures of reaching 35.5 °C was recorded in Meteorology Post (Posmet) Dumai on 16 June at 16.00 with very low air humidity of 35% < 50% [7].
During the WMT activities, the rainfall occurred almost every day encompassing various regions in the Riau Province such as Indragiri Hilir regency, Meranti, Pelalawan, and Siak with varying intensities from mild to heavy rain. The increased precipitation rate (rain) consequently minimized the number of hotspots and peat fires. The rainfall may also sweep away smoke hazard particles in the atmosphere so that the sunray may penetrate to the soil surface and make it warm enough to vaporize the surface water into the sky to perform clouds.

Figure 7 presented the fluctuation of precipitation rates within Indragiri Hilir regency, Meranti, Pelalawan, and Siak, 2014.

![Figure 7](image)

**Figure 7.** Precipitation rates in Indragiri Hilir regency, Meranti, Pelalawan, Siak, and Riau Province 2014.

Based on the Meteorology, Climatology and Geophysics Agency (BMKG), 2014 data, the dry season conditions in Riau Province occurred during the period of January-April, June-August, and September-October 2014. The temperatures were between 23-36 degrees Celsius. Based on the Global Forest Watch report, between 1st January 2014 and 1st January 2015 the Riau Province experienced a total of 117,802 Visible infrared Imaging Radiometer Suite (VIIRS) fire alert events (https://www.globalforestwatch.org).

![Figure 8](image)

**Figure 8.** Visible infrared Imaging Radiometer Suite (VIIRS) fire alert (Hot Spots) in Riau, 2014.

Based on Figure 8, in 2014 the highest fire alerts (hot spots) existed in the period of January, February, March, April, end of June, July, and early August, and September-October 2014. These hotspots occurred at the period of the dry season conditions (Figure 7, 8).

The implementation of the WMT in 2015 was 152 days (Table 2). Based on the Airport Meteorological Station (SSK) II Pekanbaru [13], Riau report 2015, the peak of the dry season in the Riau region 2015 was recorded to occur in the early January to March, and July to August, and
October. It was reported by the Global Forest Watch, at the period of 2015 Riau experienced a total of 41,712 VIIRS fire alerts, which the highest number of hotspots occurred at 3 periods such as February-April, July and early August, September to end of October. Again, the hot spot cases occurred in the dry season period.

In 2016, it was identified the total duration of WMT was 88 days (Table 2). Based on the Meteorology, Climatology and Geophysics Agency (BMKG), 2016 data, the dry season conditions in Riau Province occurred during the period of January-March, July-August, and October 2016 (Figure 12). The temperatures were in between 23-35 degrees Celsius.

Based on the Meteorology, Climatology and Geophysics Agency (BMKG), 2016 data, the dry season conditions in Riau Province occurred during the period of January-March, July-August, and October 2016. The number of hotspots in Riau, 2016 experienced a total of 15,536 VIIRS fire alerts.

3.2 Evaluation of The Effectiveness Application of WMT
The following calculation illustrated an example to calculate the effectiveness of WMT application in Meranti Island 2016 in the 4 periods of I. July; II. August; III. September, and IV. October 2016.

The average precipitation rate of 2016 WMT period of \((RT)_p = 577.05\) mm (Table 3)
The average historical precipitation rate Period I, II, III, IV \((RT)_h = (425.53+346.80+277.65)/3 = 349.99\) mm

Calculation: \[ PCH = \frac{(RT)_p}{(RT)_h} \times 100\% \]

\[ PCH = \frac{577.05}{349.99} \times 100\% \]

\[ PCH = 1.65\] (Successful) \( PCH > 1 \)

| WMT Period        | 2013  | 2014  | 2015  | 2016  | PCH     | Description                      |
|-------------------|-------|-------|-------|-------|---------|----------------------------------|
| Period I, 15-31 July | 73.32 | 23.37 | 57.05 | 197.39 | 1.649   | Successfully
|                   |       |       |       |       |         | applied in improving precipitation rates |
| Period II, Augustus | 117.70| 123.12| 136.22| 120.77|         |                                   |
| Period III, September | 195.55| 120.42| 59.78 | 213.06|         |                                   |
| Period IV, 1-6 October | 38.96 | 79.88 | 24.59 | 45.81  |         |                                   |
| Total              | 425.53| 346.80| 277.65| 577.05| 349.99  | An average of the Precipitation rate |

For evaluating the effectiveness, the application of WMT is by calculating the amount of precipitation rate during the application of the WMT compared to the average amount of precipitation rates on the previous three years period at the same time. This calculation of the effectiveness of WMT in Meranti was considered successful as the calculation yield that there was \( PCH = 1.65 > 1 \). The following table is the result of calculating the success rate of WMT in Riau Province 2014, 2015, and 2016.

3.2.1. The evaluation in the period of 2014. During the implementation of the WMT in 2014 with 143 flight sorties and the total duration of WMT was 144 days has yielded the following results (Table 4).
Table 4. The success rate of WMT in Riau Province in 2014

| No | Regency          | Period                  | PCH | Effectiveness per period | Effectiveness for total period | Descriptions        |
|----|------------------|-------------------------|-----|--------------------------|-------------------------------|---------------------|
| 1  | Indragiri Hilir  | 5 March-31 March        | 0.359 | Un-Successful           |                                |                     |
|    |                  | April                   | 0.668 | Un-Successful           |                                |                     |
|    |                  | May                     | 0.561 | Un-Successful           | 0.8938                       | Un-Successful       |
|    |                  | June                    | 2.023 | Successful             |                               |                     |
|    |                  | 1 July-24 July          | 0.858 | Un-Successful           |                               |                     |
| 2  | Kepulauan Meranti| 5 March-31 March        | 1.133 | Successful             | 1.4782                       | Successful          |
|    |                  | April                   | 0.835 | Un-Successful           |                               |                     |
|    |                  | May                     | 0.488 | Un-Successful           |                               |                     |
|    |                  | June                    | 3.801 | Successful             |                               |                     |
|    |                  | 1 July-24 July          | 1.134 | Successful             |                               |                     |
| 3  | Pelalawan        | 5 March-31 March        | 0.434 | Un-Successful           | 1.1378                       | Successful          |
|    |                  | April                   | 1.156 | Successful             |                               |                     |
|    |                  | May                     | 0.725 | Un-Successful           |                               |                     |
|    |                  | June                    | 2.695 | Successful             |                               |                     |
|    |                  | 1 July-24 July          | 0.679 | Un-Successful           |                               |                     |
| 4  | Siak             | 5 March-31 March        | 0.71  | Un-Successful           | 1.3428                       | Successful          |
|    |                  | April                   | 1.422 | Successful             |                               |                     |
|    |                  | May                     | 0.538 | Un-Successful           |                               |                     |
|    |                  | June                    | 3.157 | Successful             |                               |                     |
|    |                  | 1 July-24 July          | 0.887 | Un-Successful           |                               |                     |

The implementation of WMT activities in Riau Province in 2014 was considered successful as 4 regions’ PCH>1, although there had been an increase in sea surface temperature in the Nino 3.4 area in May and June 2014, it still showed a neutral ENSO condition. The dry phase marked by very low humidity occurs in the second week of March, the second week of April, the third week of June, and the fourth week of July 2014. Extreme weather was recorded on 16 June at 16.00 with temperatures reaching 35.5°C and 35% humidity.

Figure 9. Effectiveness Implementation of WMT in Riau 2014-2016

Based on the PCH calculation results from the Figure 9 above, it can be seen that the effectiveness of WMT activities in Riau Province for 2014 is 75% successful. During WMT activities, rain occurs almost every day in distributing in various regions in the Riau Province with varying intensities from mild to dense, so that the rain minimized the number of existing hotspots. The rainfall may also sweep away smoke particles in the atmosphere so that the smoke density is reduced, consequently the air becomes cleaner and surface water can vapor to the sky and forming the clouds.
3.2.2. The evaluation in the period of 2015. It was recorded that the implementation of WMT in 2015 had been conducted to deploy 83 flight sorties, which spent 129 hours and 31 minutes flying hours carrying 82,500 kg of seeding agent materials. In general, the humidity in Sumatra was very dry from June to October 2015 hence the effectiveness of WMT application was considered unsuccessful as PCH < 1.00.

The application of WMT is influenced by a combination of various meteorological factors such as dry season, ENSO, MJO, tropical cyclones, low pressure and local topographic factors. The dry season period was identified by there was low humidity condition in the initial first week in the March 2015, and at the end of April 2015. The emergence of several Tropical Cyclones in the waters of the Philippines / South China Sea caused disturbing in forming the clouds in the Southern Sumatra regions (South Sumatra, Jambi and Riau) due to the trend of water vapor being drawn towards the center of the cyclone. This dry weather condition has fluctuated, but up to October 2015, the dry weather condition remained stable dry to very dry. Hence, the application of WMT was reasonable to became failure.

It was summarized that the implementation of WMT had increased the average of precipitation rates (PCH) at the as PCH = 2.09 > 1.00. Hence, the implementation of WMT in the 3 periods of 2014-2016 was considered successful.

3.3 Success Criteria

The successes implementing WMT activities are largely determined by the following considerations:

- The timing initiating for the implementation of WMT. The success of WMT is influenced by the presence of clouds in the target area of WMT. Therefore, the implementation of WMT is usually performed during the transition season, either the transition from the rainy season to the dry season and vice-ver-sa. Once the WMT activities are started in the dry season, the WMT becomes less effective because in the dry season the presence of clouds is very few or rare.
- Weather conditions support the occurrence of clouds in the target area, such as humidity, wind direction and speed, temperature convection so that weather and climate control conditions will determine the success of WMTs such as La-Nina and El-Nino.
- Timeliness in performing cloud seeding (window opportunity).
- The quality of the materials used for the seedlings, especially the grain size of the materials and the moisture level of the seedlings.
- Cloud execution technique in the cloud seeding process for example using airplane which is injecting seeding agents into the cloud could be effective compared to other method.
- The number of airplane fleet sorties used for seeding process especially for large target areas.
- The parameters used for the evaluation of WMT can be varied such as; rainfall data, flow data, hotspot data, visibility data, and peatland water level data.
- The common methods used for evaluating the effective implementation of WMT are Target Only Method (TOM), Target Control and Double Ratio. This article used TOM as a method for the evaluation.

4. Conclusions

The effectiveness application of the WMT increased the precipitation rate for mitigation of peatlands fire in Riau Province, 2014-2016 was considered successful (PCH > 1.00). However, it was necessary the application of WMT would be successful as the effectiveness application of weather modification technology has not been solely based on the technical factor of artificial cloud seeding process using the airplanes, this also was influenced by various meteorological factors such as the ENSO phenomenon, MJO, tropical cyclones, low pressure and topographic factors. Hence, there was a wide room to improve better understanding for enhancing WMT performances achieving its objectives by establishing strong collaboration among academic researchers, WMT practitioners, weather and meteoroidal experts.
5. Acknowledgment
The authors would like to thank Balai Besar Teknologi Modifikasi Cuaca - BPPT, UPT - HB BPPT, Unit Pelaksana Teknis Hujan Buatan, BPPT, Indonesia, INSINAS grants from Dirjen Dikti, Dikbud, LPPM UNRI for the cooperation and research collaboration with our research team. The special thanks we dedicated to Dr. Sigit Sutikno, M A Perdana, and Dr. Tri Handoko Seto for their contribution in discussing this topic before developing this article.

References
[1] Minayeva T Y, Bragg O M and Sirin A A (2017) Towards ecosystem-based restoration of peatland biodiversity Mires Peat 19 1–36 doi: 10.19189/MaP.2013.OMB.150
[2] Bonn A, Allott T and Evans M 2016 Peatland restoration and ecosystem services: Nature-based solutions for societal goals. Peat Restore Ecosystem Service Social Policy Practices 402–417 doi: 10.1017/CBO9781139177788.021
[3] Parish F, Sirin A and Charman D 2008 Assessment on Peatlands, Biodiversity and Climate Change: Main Report Global Environment Centre, Kuala Lumpur & Wetlands International, Wageningen
[4] Adesiji A, Mohammed T and Nik D N 2015 Impacts of land use change on peatland degradation: a review Ethiop J Environ Stud Manag 8 225 doi: 10.4314/ejesmv8i2.11
[5] Sabiham S, Winarna and Pulunggono H B 2016 What is the way forward on Indonesian Peatland? 15TH INTERNATIONAL PEAT CONGRESS 2016 39–45
[6] Sandhyavitri A, Perdana M A, Sutikno S and Widodo F H 2018 The roles of weather modification technology in mitigation of the peat fires during a period of dry season in Bengkalis, Indonesia TALENTA-CEST, IOP Conf. Series: Materials Science and Engineering IOP Publishing 0–9
[7] Seto T H and Mulyana E 2013 Usulan Pemanfaatan Teknologi Modifikasi Cuaca dengan Ground-based Generator untuk Menambah Debit Aliran Sungai Mamasa J Sains Teknol Modif Cuaca 14 BPPT, Jakarta
[8] Defelice T P and Axisa D 2017 Modern and prospective technologies for weather modification activities : Developing a framework for integrating autonomous unmanned aircraft systems Atmos Res 193 173–183 doi: 10.1016/j.atmosres.2017.04.024
[9] Bahri S 2002 Kajian Penyebaran Kabut Asap Kebakaran Hutan dan Lahan di Wilayah Sumatera Bagian Utara dan Kemungkinan Mengatasinya dengan WMT J Sains Teknol Modif Cuaca 3 99–104
[10] Sutikno S, Handayani Y L, Fauzi M and Kurnia A 2017 Hydrologic modelling using TRMM-based rainfall products for flood analysis 05015 2–6
[11] Hendra Y, Fauzi M and Sutikno S 2015 Hybrid Data Hujan ARR dan Satelit Guna Peningkatan Efektifitas Model IFAS Proc. ACES (Annual Civ. Eng. Semin 1 61–72
[12] Tan M, Ibrahim A and Duan Z 2015 Evaluation of Six High-Resolution Satellite and Ground-Based Precipitation Products over Malaysia Remote Sens 7 1504–1528. doi: 10.3390/rs70201504
[13] Airport Meteorological Station (SSK) II Pekanbaru, Riau loose report 2015. The peak of the dry season in the Riau region 2015 in https://www.wartaekonomi.co.id/read42544/bmkg-riau-masuki-musim-kemarau.html