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Analysis of the Relationship Between Aerosol Optical Depth (AOD) and Particulate Concentration (PM2.5) for Determining the Standard Index of Air Pollution in Jambi Province

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Abstract

Introduction: *Forest and land fires (karhutla) frequently occur in Jambi Province, Indonesia, as indicated by numerous hotspots detected annually.* ***Objective:*** *This study aims to analyze the sources and impacts of karhutla on PM2.5 concentrations, Aerosol Optical Depth (AOD), Angstrom Exponent (AE), and the Air Pollutant Standard Index (ISPU) based on in-situ measurements, as well as to establish an empirical relationship between PM2.5 and AOD for application to Terra-Aqua Satellite AOD (MCD19A2).* ***Method****: The data for 2022–2024 were analyzed with the support of the HYSPLIT model and Google Earth Engine.* ***Results and Discussion:*** *Results show a significant increase in hotspots during September–October 2023, indicating extensive fires in Jambi and South Sumatra. PM2.5 concentrations surged to 265.6 µg/m³ in September and 307.4 µg/m³ in October, mainly originating from these regions. Air quality deteriorated, with Unhealthy and Very Unhealthy categories increasing to 31.3–40.1% and 1.7–3.2%, respectively, while Hazardous levels reached 0.3–0.4%. AOD at 440 nm peaked at 2.651 during September 4–October 24, 2023, with AE values between 1.51 and 1.57, confirming fine particles from biomass burning. AOD and PM2.5 showed a positive correlation, expressed by the linear regression equation Y = 36.289x + 13.232 (Y = PM2.5, x = AOD 470 nm).* ***Conclusion:*** *Validation of ISPU from MCD19A2 against ISPU from AQMS measurements resulted in an accuracy of 46.96% without distinguishing the type of pollutant, and 61.67% if the determining parameter is PM2.5.*

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Introduction

Forest and land fires (KARHUTLA) are environmental problems that often occur during the dry season in Indonesia, especially in areas that still have forest and plantation areas such as the islands of Sumatra and Kalimantan. The impacts of forest and land fires have a wide and diverse spectrum. The transportation sector, especially aviation, is a sector that is very affected because smoke from fires interferes with horizontal visibility when airplanes are taking off and landing at the airport. In some locations, airports have even been closed due to the thick smoke from forest and land fires. Another equally important sector affected by smoke is the Health sector. Forest and land fires in 2015 in the provinces of Riau, Jambi and South Sumatra caused the worst disaster in the last 18 years, which had a very severe impact on air pollution in several Southeast Asian countries (Amri et al., 2024)

Geographically, Jambi Province is located between 0o45' – 2o45' South Latitude and 101o10' – 104o55' East Longitude. In the south, Jambi Province directly borders South Sumatra Province, in the north it borders Riau Province, in the west it borders West Sumatra Province and Bengkulu Province, and in the east it borders the East Coast and Berhala Strait. Topographically, in the east to the center, the Jambi Province area is dominated by lowlands with an altitude of 0-100 m with a percentage of around 69.1%. Forest vegetation is spread throughout the Regency except Jambi City and Sungai Penuh City. Jambi Province has the third largest peatland area on Sumatra Island. Peatlands are spread across Muaro Jambi Regency, West Tanjung Jabung Regency and East Tanjung Jabung Regency with a total area reaching 736,227.20 ha or around 14% of the area of Jambi Province. Land cover on peatlands varies including forests, agricultural land, and plantation land. This peatland is also often the location of forest and land fires, especially during the dry season.

The area of forest and land burned during the period from January to September 2023 in Jambi Province reached more than 335 hectares and was spread across 27 points. Based on data and records from the Jambi KARHUTLA Task Force via the KARHUTLA application in Jambi Province, the areas that burned the most were in Batang Hari, Tebo, Merangin, Bungo, Muaro Jambi, West Tanjung Jabung and East Tanjung Jabung and Sarolangun Regencies. Details of the total area burned in Jambi Province in Batang Hari Regency were 111.14 ha, Sarolangun 40.02 ha, Tebo 31.20 ha, West Tanjung Jabung 16.13 ha, Merangin 9.80 ha, Bungo 9.45 ha, Muaro Jambi 7 ha and East Tanjung Jabung Regency 4.80 ha. (Mairiadi, 2023).

In Jambi Province, forest and land fires occur almost every year, especially during the dry season influenced by a global event called El Nino (an event marked by an increase in sea surface temperatures in the Central to Eastern Pacific Ocean, resulting in a significant decrease in rainfall in the western part of Indonesia). Satellite imagery helps find hotspots, where in Jambi Province most hotspots are detected on peatlands. Jambi Province has the 3rd largest peatland on the island of Sumatra. The area of peatland in Jambi Province reaches 736,227.20 ha or around 14% of the area of Jambi Province (Hariyadi, 2019). The impact of these fires causes potential losses that cannot be measured financially, such as loss of biodiversity, changes in ecosystems and the environment, and the possibility of disruption of wildlife habitats (Ramadani et.al., 2023), also impacting neighboring countries such as Malaysia and Singapore due to the smoke spreading from the fires (Am, 2020).

In addition, forest and land fires also produce large emissions of carbon dioxide gas and other atmospheric pollutants. These fires cause the concentration of particulate matter (PM) of various sizes to increase, such as PM2.5, which is particulates with a size of ≤ 2.5 micrometers (Yulianti, 2018). PM2.5 is a form of air pollutant that contributes to the deaths of 7 million people per year due to exposure to air pollution (WHO, 2012). Forest and land fires cause and significant decline in air quality, including through spikes in PM2.5 concentrations that exceed healthy thresholds (≤ 15.5 µg/m3), which have a direct impact on public health in Jambi Province, especially an increase in respiratory diseases. The Jambi City Health Office recorded that 10 thousand residents were attacked by Acute Respiratory Tract Infections (ARI) throughout July and August 2023. The number of ARI cases in Jambi City in July reached 5,310 cases while in August it increased to 5,477. (Nan et al., 2023); (Syafaati, 2023); (Sidiq, 2024); (detikSumbagsel Team, October 2, 2023).

Forest and land fires not only produce particles of various sizes, which have certain chemical characteristics, but the burning of biomass (forest vegetation and production plants) also emits various gases, both pollutants and greenhouse gases. Particles from fires are dominated by organic carbon and black carbon which accelerate climate change through global warming (Yokelson et al., 2007); Ditas, 2018). These pollutant gases include Sulfur Dioxide (SO2), Nitrogen Dioxide (NO2), and Carbon Monoxide (CO). These gases are toxic and therefore harmful to health at certain concentrations. Meanwhile, greenhouse gases include Carbon Dioxide (CO2) and Methane (CH4). These gases are not toxic, but have a major impact on long-term climate change. These pollutant gases and greenhouse gases will shape the chemical properties of the atmosphere during the fire period which are likely to be very different from non-fire conditions (Saidal Siburian & Mar, 2020); (Orach, Rider, & Carlsten, 2021).

In 2020, the Ministry of Environment and Forestry issued Regulation of the Minister of Environment and Forestry Number 14 of 2020 concerning the Air Pollutant Standard Index which replaces Decree of the Minister of Environment No. 45 of 1997 concerning Calculation and Reporting and Information on the Air Pollutant Standard Index. In this replacement regulation, it is stated that the ISPU calculation is carried out on 7 (seven) parameters, namely PM10, PM2.5, NO2, SO2, CO, O3, and HC. There are 2 (two) additional parameters, namely HC and PM2.5 from the previous regulation. The addition of these parameters is based on the magnitude of the risk of HC and PM2.5 to human health. In addition to the addition of parameters, there is an increase in the frequency of delivering ISPU information to the public. The results of the ISPU calculation of the PM2.5 parameter are conveyed to the public every hour for 24 hours. Meanwhile, the results of the ISPU calculation of the PM10, NO2, SO2, CO, O3, and HC parameters are conveyed to the public at least 2 (two) times in 1 (one) day at 09.00 and 15.00.For information regarding the PM2.5 parameter which is the air pollutant parameter that has the most influence on human health (Chaniago, Zahara, & Ramadhani, 2020)

The increase in the number of particles in the atmosphere due to forest and land fires, in addition to increasing the concentration of PM2.5, also affects the Aerosol Optical Depth (AOD) value which represents the optical properties of the atmosphere. Aerosols are all solid and liquid particles suspended in the atmosphere. Solid particles come from natural sources such as volcanoes, desert dust, beach sand, pollen, sea wave spray, and so on. Aerosol sources also come from anthropogenic (human activities) such as fossil fuel combustion, forest and land fires, construction, and others.

The presence of aerosols in the atmosphere blocks sunlight radiation which causes a decrease in the intensity of direct sunlight received by the earth's surface. The more aerosols in the atmosphere, the higher the AOD value measured by the Sunphotometer, and vice versa. This study focuses on the analysis of the physical and optical properties of the atmosphere. Physical properties are represented by ambient PM2.5 concentrations, and optical properties are represented by AOD, to provide an overview of the differences in these parameters in the period 2022-2024. Further analysis will be conducted to determine the relationship between PM2.5 concentration and AOD so that an empirical equation is obtained that is useful for estimating PM2.5 concentration in Jambi Province even though there is no PM2.5 measuring equipment.

The availability of AOD data from various satellites can be easily accessed by the public, so that by using this empirical equation, the PM2.5 concentration at any point can be estimated as long as the satellite AOD data at that point is known. In addition, satellite AOD data is also useful for determining the distribution of estimated PM2.5 concentration in an area. The Sultan Thaha Meteorological Station, which is an Integrated Service Unit of the Meteorology, Climatology and Geophysics Agency in Jambi City, has complete equipment to observe PM2.5 concentration, AOD, and the chemical properties of the atmosphere. Measurement of the chemical properties of the atmosphere is measured through rainwater. Rainwater will dissolve particles and interact with gases in the atmosphere, then samples are taken to examine their chemical content. AOD measurements were conducted using the Sunphotometer equipment, which is a global Aerosol Robotic Network (AERONET) owned by the United States space agency NASA (National Aeronautics and Space Administration). While PM2.5 was measured using the BAM 1020 Analyzer which provides ambient PM2.5 concentrations every hour.

This study was born from new ideas about the importance of aerosol research through analysis of physical properties (represented by PM2.5 concentration) and optical (represented by AOD) in the period 2022-2024. Most AOD studies that use satellite data during forest and land fires generally do not cross-validate with in-situ data such as AERONET. In addition, the AOD to PM2.5 conversion approach has not been widely applied in Indonesia. The limitations of expensive in-situ PM2.5 monitoring tools are the main obstacle in obtaining the spatial distribution of PM2.5.

This study is important to utilize AOD data from AERONET and the Terra-Aqua satellite equipped with NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) sensor as an alternative approach to determining PM2.5 concentration during forest and land fires. MODIS provides AOD over land and sea during the day twice, namely around 10:00-12:00 WIB and 12:30 - 14:30 WIB (Hu, Brunsell, Monaghan, Barlage, & Wilhelmi, 2014). The ease of access to AOD data from various satellites provides the public with the opportunity to estimate PM2.5 concentrations and their distribution, from the results of converting AOD and PM2.5 in-situ data. The estimated PM2.5 concentration can be used to determine the Air Pollutant Standard Index at the location, even though there is no PM2.5 measuring equipment, so that preparedness efforts to face the impact of KARHUTLA on health can be immediately determined.

Method

This study uses computer devices to process data. The materials used are in-situ AOD measurement data with NASA's AERONET Sunphotometer, PM2.5 concentration with BAM1020 equipment, rainfall, wind direction and speed at the Sultan Thaha Jambi Meteorological Station. This study was conducted for 3 (three) months starting from March to May 2025, located in Jambi City, Jambi Province.

Results and Discussion

Analysis of Sources and Impacts of Forest and Land Fires on Increasing Particulate Concentration (PM2.5), Air Quality Status, Aerosol Optical Depth (AOD) Values and Angstrom Exponent (AE)

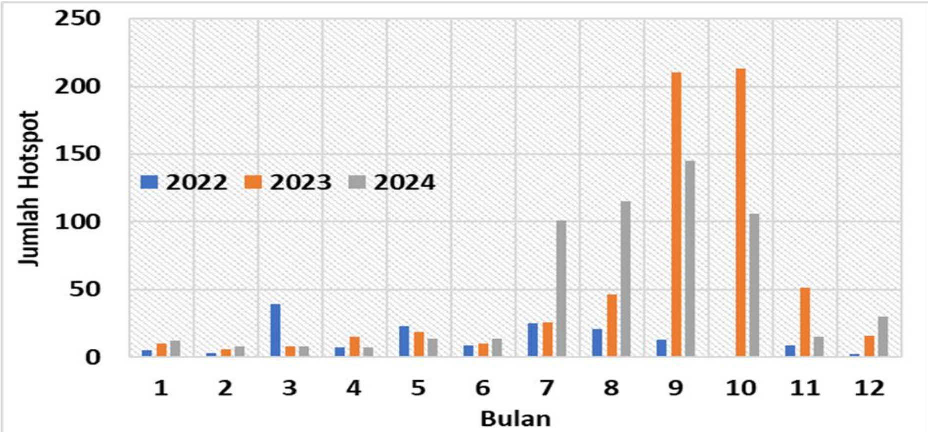

Figure 1. Monthly hotspot count taken from MODIS sensors on Terra and Aqua Satellites in 2022-2024 in Jambi Province

Figure 1 shows a graph of the number of monthly hotspots in Jambi Province in 2022-2024. In July-October, coinciding with the dry season, the number of hotspots increased sharply compared to the number of hotspots in the rainy season (December - June). The number of hotspots in the dry season in 2023, especially in September and October, amounted to 210 and 213 points, a sharp increase compared to the same period in 2022 (145 and 105 points) and 2024 (1 and 13 points). The number of monthly hotspots taken from the MODIS sensor on the Terra and Aqua Satellites in 2022-2024 in South Sumatra Province is as shown in Figure 2 below

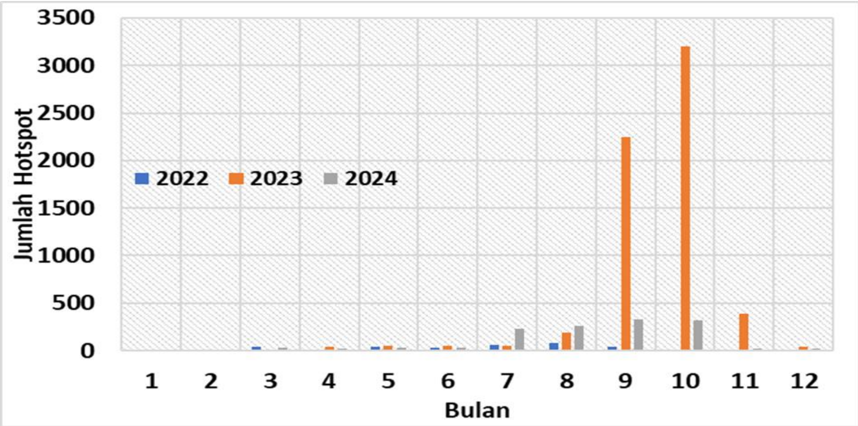

Figure 2. Monthly hotspot count taken from MODIS sensors on Terra and Aqua Satellites in 2022-2024 in South Sumatra Province.

Figure 2 shows a graph of the number of hotspots in South Sumatra Province in 2022-2024 taken from the same source. In South Sumatra Province, the number of hotspots spikes in the dry season (July - November) and vice versa in the rainy season (around December - May). For 2023, especially for September and October, the number of hotspots also increased sharply to 2,248 and 3,200 points, compared to 40 and 15 points in 2022, and 329 and 316 points in 2024 in the same period. In Jambi Province, the distribution of hotspots was concentrated mostly in the North, Central and South regions in September, and the same region plus the East region for October. Meanwhile, for South Sumatra Province, hotspots were evenly distributed for both time periods with the dominance of the East and South regions which are peatland locations. The dominant wind speed direction in September and October 2023 was from the Southeast to the South with an average speed of 3-18 knots. This caused the smoke from forest and land fires from South Sumatra to be carried to Jambi Province, and the smoke from Jambi Province moved to areas in the Southeast to the South of Jambi Province such as Riau Province and West Sumatra.

To determine the percentage of wind direction and speed in September to October in the cardinal directions in Jambi Province, windrose analysis was carried out from hourly wind direction and speed data at the Sultan Thaha Jambi Meteorological Station in August, September, October and November 2023. In line with the wind distribution map as shown in Figures 4.3 and 4.4, where the dominant wind in September and October 2023 is from the Southeast to the South. Windrose confirms that the dominant wind in Jambi City also comes from the Southeast, which is divided into 2, namely East South East/ESE (112.5o) with a percentage of ± 20%, and South South East/SSE (157.5o) with a percentage of ± 22%, and speeds ranging from 2-14 knots. The next largest wind direction is east with a percentage of ± 10% and south with a percentage of ± 7.5%. The Windrose diagram for August-November 2023 in Jambi Province can be seen in Figure 3 below.

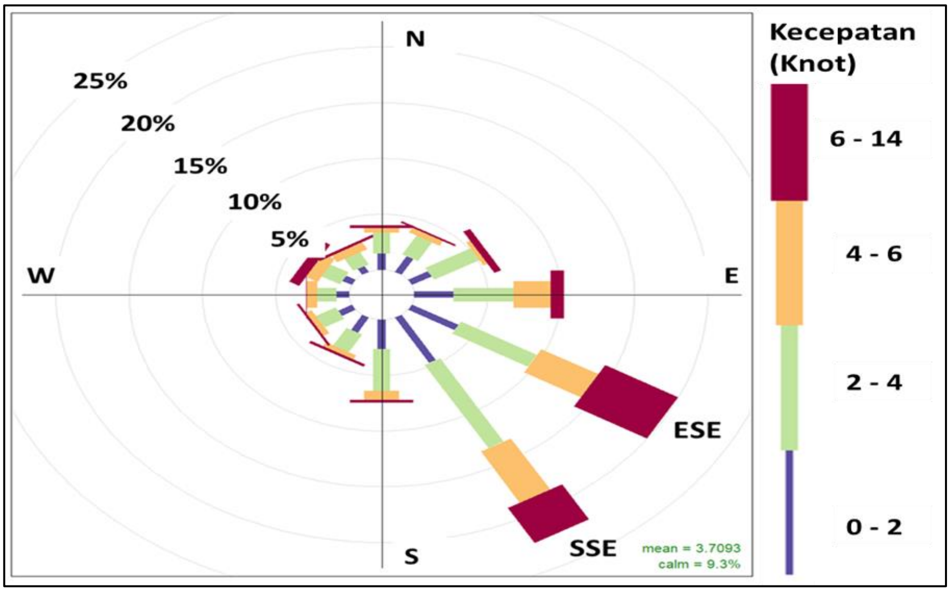

Figure 3. Windrose Diagram for August-November 2023 in Jambi Province

HYSPLIT was developed by the National Oceanic and Atmospheric Administration (NOAA) and is one of the commonly used models to analyze the trajectory and dispersion of pollutants. In this study, the Hysplit Model is used to analyze the movement or distribution of smoke from the source, in this case a hotspot that has a high level of confidence (> 80%), combined with a numerical weather prediction model. Here, the numerical model chosen is the Global Forecast System (GFS) from NOAA which has a resolution of 0.25º x 0.25º which is able to predict the weather in several dimensions (space, time and altitude) up to 16 days in advance. There are other NWP product options that can be used, such as the Global Data Assimilation System (GDAS) and reanalysis, but the resolution is too coarse, namely 0.5º and 1º, and the data capacity is very large. Given the large number of hotspots in the period above, this study will only take a few hotspot events at a certain time. The smoke movement time with a 2-hour interval calculated from the hotspot location on September 25, 2023 and ending on September 26, 2023 can be seen in Figure 4 below.

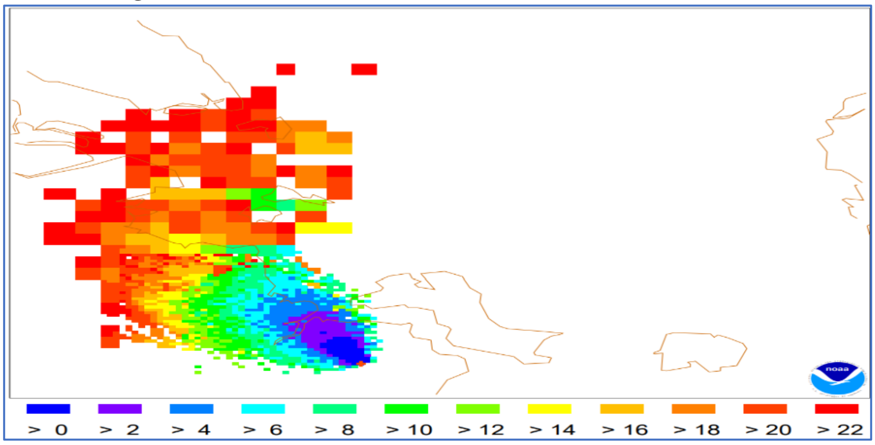

Figure 4. Smoke movement time with 2-hour intervals calculated from the hotspot location on September 25, 2023 and ending on September 26, 2023.

Figure 4 shows the results of the Hysplit Model analysis run from a collection of hotspot points with an initial time on September 25, 2023 at 00 UTC (07.00 AM) at the location of 3.106º LS 105.223º BT (South Sumatra region) until 24 hours later. Smoke from fires spreading from South Sumatra interacts with the numerical weather model from the Global Forecast System producing smoke movement every 2 hours. Analysis of the distribution of smoke/particles on September 26, 2023 in Figure 5 below.

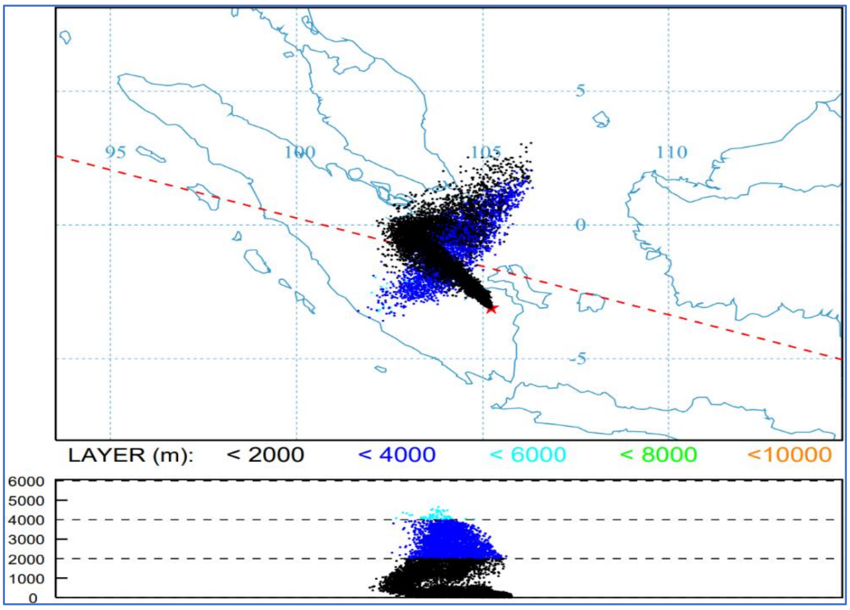

Figure 5. Analysis of smoke/particle distribution on September 26, 2023

Figure 5 shows the distribution of smoke on September 26, 2023 at 00.00 UTC originating from the selected hotspot on September 25, 2023. The wind from the Southeast to the South carried the smoke to the Northwest to the North. About 8 or 10 hours later, the smoke entered the Jambi Province and continued to spread further to Riau Province and Singapore. Smoke from fire sources contains particles of various sizes carried by the wind and measured by BAM-1020 installed at the Sultan Thaha Jambi Meteorological Station. The PM2.5 Concentration Plot Calendar for August, September, October and November 2023 can be seen in Figure 6 below.

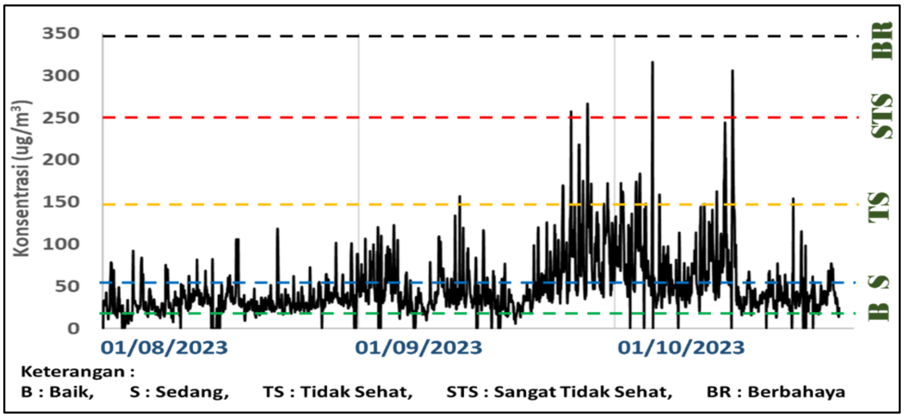

Figure 6. PM2.5 Concentration Plot Calendar for August, September, October and November 2023.

Figure 6 shows the hourly PM2.5 concentration graph in August, September and October 2023. PM2.5 concentration in August 2023 ranged from 3.7 to 118.7 µg/m3 with an average value of 33.2÷15.7 µg/m3. Concentration in September 2023 ranged from 4.8-265.6 µg/m3 with an average value of 52.7÷34.4 µg/m3. Meanwhile, for October 2023, the concentration was in the interval of 12.8-307.3 µg/m3 with an average of 62.9÷39.7 µg/m3. The concentration was relatively stable at a concentration of <54.5 µg/m3 since August 1, 2023, then increased to 100 µg/m3 and fluctuated between 15.6-100 µg/m3 until mid-September 2023 before then increasing drastically to reach 265.6 µg/m3 and varying at a relatively high concentration level until then decreasing in the first week of October 2023. The concentration then jumped sharply again to 307.3 µg/m3 and then decreased again to a relatively low concentration level until the end of October 1, 2023.

Analysis of the Impact of Forest and Land Fires on Air Quality Status shows the frequency distribution of PM2.5 concentration per hour in August 2023 dominated by the Moderate category (90%) followed by Unhealthy (7.4%) and Good (5.5%). In September 2023, the Moderate level dropped to 60.8% while Unhealthy rose sharply to 31.3%, and new categories emerged, namely Very Unhealthy (1.7%) and Hazardous (0.3%). Meanwhile, in October 2023, the Moderate category dropped again to 55.6%, Unhealthy rose to 40.1%, Very Unhealthy also rose to 3.2% followed by Hazardous (0.4%).

Analysis of the Relationship Between Particulate Matter (PM2.5) Concentration and Aerosol Optical Depth (AOD) Based on In-Situ Measurements

There are several similarities in the measurement of PM2.5 and AOD at the Sultan Thaha Jambi Meteorological Station, namely the similarity of location and time of measurement, and more importantly, the object of measurement, namely the atmosphere. What distinguishes the two measurements is that PM2.5 represents the physical condition of the atmosphere while AOD represents the optical condition of the atmosphere. In addition, there are 2 overlapping events, namely during forest and land fires, the concentration of PM2.5 increases, and the AOD value increases. Departing from this understanding, this study feels the need to find the relationship between PM2.5 and AOD, considering that both parameters are in-situ measurements and are point location measurements, and only represent measurements at that point. It is difficult to determine how wide the coverage or representation of these measurements is. This limitation can be filled by utilizing satellite data which provides a lot of AOD data that can be freely accessed in the public domain. The graph of the daily average AOD 340 nm and PM2.5 concentration in August to October 2023 can be seen in Figure 7 below.

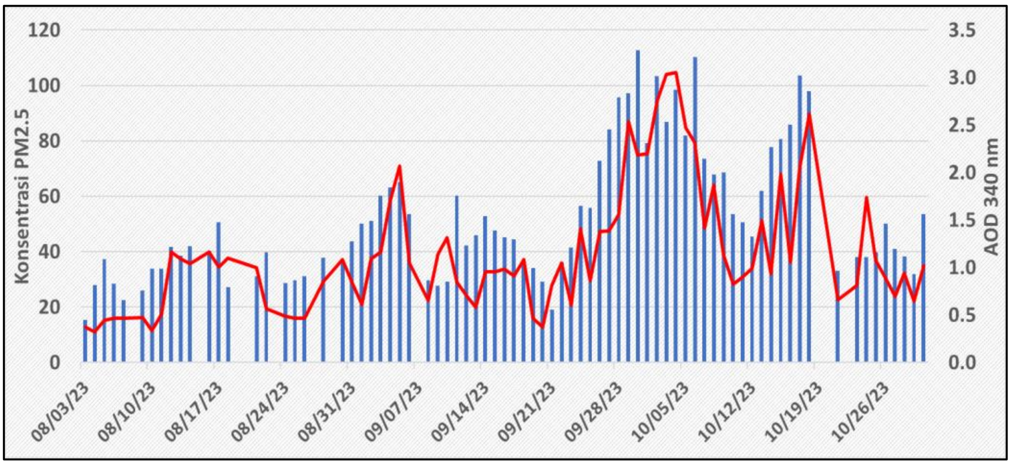

Figure 7. Graph of daily average AOD 340 nm (red line) and PM2.5 concentration (blue histogram) in August to October 2023.

Figure 7 is a graph of PM2.5 concentration (blue histogram) superimposed on AOD 340 nm (red line) for the period 1 August – 31 October 2023. There is almost the same pattern between the two parameters. When the PM2.5 concentration increases, the AOD 340 nm value also increases, and vice versa.

Table 1
Relationship between PM2.5 and AOD at various wavelengths in the period 2022 – 2024.

Variables	Pearson Correlation	Regression Equation	R-Squared
AOD 340 nm	0.79	Y = 29.619X + 12.37	0.63
AOD 380 nm	0.79	Y = 31.372X + 12.94	0.62
AOD 440 nm	0.78	Y = 35.002X + 13.74	0.60
AOD 500 nm	0.77	Y = 39.743X + 14.04	0.59
AOD 675 nm	0.75	Y = 57.237X + 14.96	0.56
AOD 870 nm	0.72	Y = 81.519X + 15.04	0.52
AOD 1020 nm	0.70	Y = 99.914X + 15.29	0.49
AOD 1640 nm	0.55	Y = 130.57X + 19.19	0.30

The correlation coefficient decreases as the AOD wavelength increases, as does the determination coefficient. Thus, AOD 340 nm is a good predictor for estimating PM2.5 concentration, and AOD 1640 nm is the worst predictor for estimating PM2.5 concentration.

Estimation of PM2.5 Concentration Using AOD MCD19A2 Based on Empirical Equation of PM2.5 and AOD Relationship from In-Situ Measurements

Interpolated AOD 470 and 550 nm (in-situ) graphs juxtaposed with in-situ AOD 340 nm. Both interpolated AODs have the same pattern as the 340 nm AOD, the only difference is the magnitude or value where the 340 nm AOD value> interpolated 470 nm AOD> interpolated 550 nm AOD. This is because the larger the wavelength, the greater the penetration power, so the AOD value is smaller. It should be noted that this AOD interpolation was carried out throughout 2022-2024.

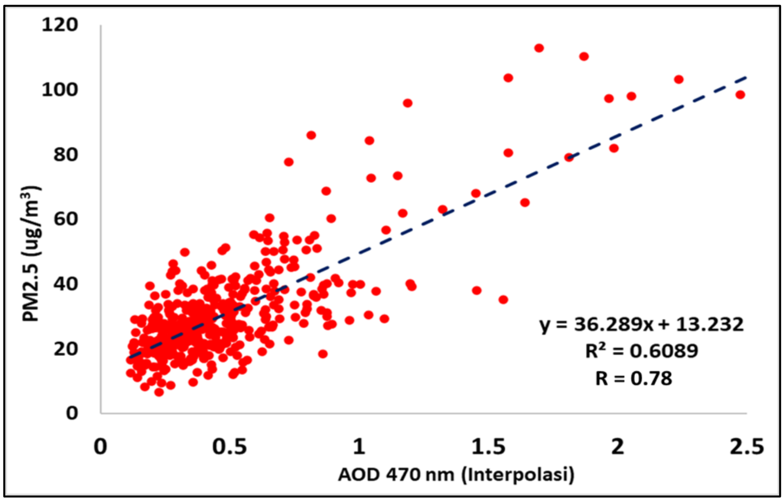

Figure 8. Relationship between AOD 470 nm from in-situ AOD data interpolation (AERONET) and PM2.5 concentration in 2022 – 2024.

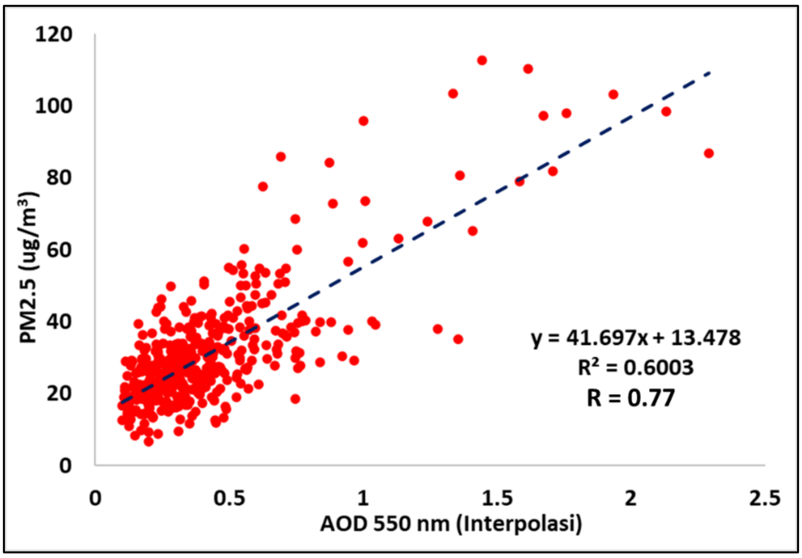

Figure 9. The relationship between AOD 5500 nm from in-situ AOD data interpolation (AERONET) and PM2.5 concentration in 2022 – 2024.

The interpolated AOD 470 nm is a better predictor compared to the interpolated AOD 550 nm for estimating PM2.5 concentration, because it has a higher Determination Coefficient and Correlation Coefficient.

Table 2
Validation of Air Pollutant Standard Index (ISPU) Results of PM2.5 Concentration Estimation from AOD 470 nm MCD19A2 Against AQMS in Jambi City.

Status	ISPU AQMS (DAY)	Determining Parameters*	ISPU Versi AOD MCD19A2 (Day)**
Good	135	CO, HC, NO_2, O_3, PM_{10}, $PM_{2,5}$, SO_2	25
Currently	91	CO, HC, NO_2, O_3, $PM_{2,5}$, SO_2	83
Not healthy	4	$PM_{2,5}$	-
Very Unhealthy	-	-	-
Dangerous	-	-	-
AMOUNT	230		108
Accuracy (%)			**46.96**
Good	60	$PM_{2,5}$	9
Currently	56	$PM_{2,5}$	53
Not healthy	4	$PM_{2,5}$	-
Very Unhealthy	-	$PM_{2,5}$	-
Dangerous	-	$PM_{2,5}$	-
AMOUNT	120		62
Accuracy (%)			**51.67**

The results of the validation of the ISPU MCD19A2 status level against the ISPU AQMS, there are 135 Good statuses on the ISPU AQMS, but only 25 were successfully estimated by MCD19A2, while for the Moderate category, out of 91 days only 83 days have a category match with the ISPU MCD19A2. For the Unhealthy level, none of them match the ISPU MCD19A2. Thus, the accuracy of the match is only 46.96%. If the validation is only focused on the ISPU AQMS with the PM2.5 determining parameter, out of 60 days of Good status, only 9 days were successfully predicted by the ISPU MCD19A2, and out of 56 Moderate categories, there are 53 days that match MCD19A2. Meanwhile, for the Unhealthy level, none of them were successfully predicted. Thus, the accuracy of the match is 51.67%. The large number of category mismatches as explained above is thought to be caused by several factors, including:

a. Differences in the height of the observed particles. In-situ PM2.5 measuring devices and AQMS measure concentrations at the earth's surface level, while AOD measured by Sunphotometer and Satellite is observed from the earth's surface to the top of the atmosphere with outer space.
b. AQMS measures pollutant concentrations for 24 hours and determines ISPU based on the average concentration of the determining parameters during that period. MCD19A2 is measured by MODIS on the Terra and Aqua Satellites only twice a day, around 10:30 WIB and 13:30 WIB.
c. AQMS measures PM2.5 and PM10 concentrations only, while Sunphotometer and Satellite measure AOD with all particle sizes up to >100 microns.

To limit the data taken to only Jambi Province data, a shapefile (*.shp) is required to be uploaded to the GEE server and functions as a data cutter (clip). Computation is performed on each AOD pixel at the previously specified time. After the computation is performed, the next script will classify the Particulate ISPU category (PM2.5) based on the estimated PM2.5 concentration range number and its color status. The ISPU range number category is made by referring to Attachment II of PermenLHK No. 14 of 2020, as in Table 3

Table 3
ISPU Range Number Categories

Categories	Color Status	Range Numbers
Good	Green	0 - 50
Currently	Blue	51 - 100
Not healthy	Yellow	101 - 200
Very Unhealthy	Red	201 – 300
Dangerous	Black	≥ 301

Thus, this application is very practical to use, because users only need to enter/write the desired date in the script editor (where to write the script), save it by pressing the "Save" button, run it by pressing the "Run" button, then select the desired display by pressing the check mark on the map display, which includes: PM2.5 concentration, areas with the Particulate ISPU (PM2.5) category: Healthy, Moderate, Unhealthy, Very Unhealthy, and Dangerous.

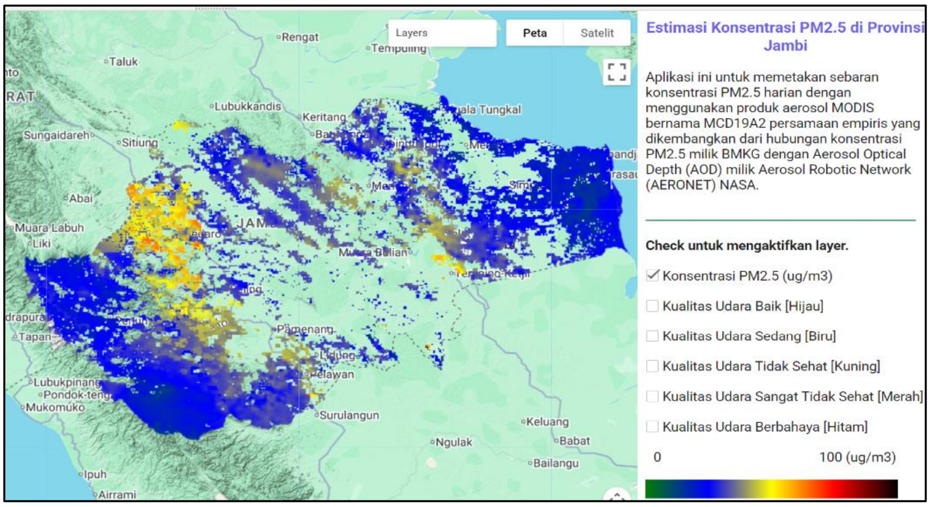

Figure 10. Output map display in Google Earth Engine after a series of commands in thescript panel are executed

By knowing the Particulate ISPU Category (PM2.5), the government can determine policies related to what should be done, by referring to the explanatory table of ISPU values according to Attachment II of PermenLHK No. 14 of 2020, as in Table 4 below.

Table 4
Explanation of ISPU Values

Category	Information	Apa yang harus dilakukan
Good	Very good air quality level, no negative effects on humans, animals, plants	It's great to do outdoor activities
Currently	Air quality levels are still acceptable for human, animal and plant health.	**Sensitive groups:** Reduce prolonged or heavy physical activity. **Everyone:** Can still do activities outside
Not healthy	Air quality levels that are detrimental to humans, animals and plants	**Sensitive groups:** Outdoor activities are allowed, but take frequent breaks and do light activities. Watch for symptoms such as coughing or shortness of breath.People with asthma should follow health guidelines for asthma and keep asthma medication on hand. **People with heart disease:** Symptoms such as palpitations, shortness of breath, or unusual fatigue may indicate a serious problem. **Each person:** Reduce physical activity that lasts too long outdoors
Very Unhealthy	Air quality levels that may increase health risks in some segments of the exposed population	**Sensitive groups:** Avoid all outdoor activities. Increase indoor activities or reschedule them. **Each person:**
Dangerous	Air quality levels that can cause serious health harm to the population and require urgent action	Avoid prolonged physical activity outdoors, consider keeping incentive groups indoors and activities small. **Each person:** Avoid all outside activities

Conclusion

Based on the cafe business standards of the Regulation of the Minister of Tourism and NASA hotspot data shows a significant increase in hotspots in Jambi Province from August to October 2023. The wind pattern from Southeast-South has the potential to bring smoke from South Sumatra to Jambi, causing a spike in PM2.5 concentrations to reach unhealthy to hazardous air levels. The AE value of 500_870 nm increased, indicating the dominance of fine particles typical of forest and land fires. In-situ measurements show a positive correlation between PM2.5 and AOD, with the highest correlation strength at a wavelength of 340 nm ($r = 0.79$; $R^2 = 0.63$). The correlation decreases with increasing wavelength. Due to the difference in wavelength, in-situ AOD needs to be interpolated (2nd order polynomial) to match satellite AOD (470 nm and 550 nm). The analysis results produce the best empirical equation for AOD 470 nm ($Y = 36.289x + 13.23$; $r = 0.78$; $R^2 = 0.6089$) for PM2.5 estimation.

The PM2.5 concentration estimation from AOD 470 nm MCD19A2 was converted to ISPU based on PerMen LHK No. 14 of 2020. Compared to ISPU from AQMS Jambi City, the accuracy reached 49.96%, increasing to 51.56% when PM2.5 was the main parameter. A Google Earth Engine (GEE)-based application was developed for PM2.5 spatial estimation using AOD MCD19A2 and empirical equations that had been built from in-situ data.

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