



GEORGETOWN UNIVERSITY
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Where There's Fire, There's Smoke: Correlating Wildfire Activity with PM2.5 In
Los Angeles, California and Jakarta, Indonesia

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Abstract

Wildfire activity is an increasing environmental and public health concern, as wildfire smoke releases fine particulate matter (PM_{2.5}) that can adversely affect respiratory and other health outcomes. This study investigates the relationship between wildfire activity and ambient PM_{2.5} concentrations in Los Angeles County and Jakarta, Indonesia. Fire activity was measured using fire radiative power from NASA's NOAA-21 satellite and correlated with daily average PM_{2.5} measurements from EPA and OpenAQ ground monitors. For each monitor-day, wildfire activity was calculated using fire detections within a 25-km radius of the PM_{2.5} monitor, including total number of fires, total FRP, and distance-weighted FRP. In Los Angeles, the strongest relationship between wildfire activity and ambient PM_{2.5} was observed for the total number of fire detections within 25 km of the three monitors closest to the Palisades Fire, with a statistically significant positive correlation (Pearson's $r = 0.4985$, $R^2 = 0.2485$, $p = 2.21 \times 10^{-36}$). In comparison, correlations between wildfire activity metrics and ambient PM_{2.5} were substantially weaker in Jakarta, suggesting that wildfire activity accounted for less of the observed variation in ambient PM_{2.5} in Jakarta than in Los Angeles. These findings demonstrate that regional differences lead to different sources of ambient PM_{2.5} and further research is needed to determine the health effects of wildfire-specific PM_{2.5}.

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Introduction

Wildfires are an increasingly pressing environmental and public health concern in Southern California. As a result of warmer and drier conditions, area burned in Southern California is predicted to double by the middle of 2050 [1]. In particular, the January 2025 Los Angeles wildfires, also known as the Palisades and Eaton fires, became among the most destructive wildfires in California history, collectively burning over 47,900 acres [2].

One major impact of wildfires is the release of fine particulate matter (PM_{2.5}) through combustion. Wildfire smoke contains substantial amounts of PM_{2.5}, which can be transported beyond the immediate area of a fire and contribute to elevated ambient air pollution in surrounding communities [3]. Los Angeles is particularly vulnerable to this additional source of pollution because of its already high levels of ambient PM_{2.5}. In 2025, the Los Angeles metropolitan area ranked 5th worst in the United States for year-round particle pollution and 7th worst for short-term particle pollution [4]. PM_{2.5} is especially concerning because its small size allows it to penetrate deep into the respiratory system. Exposure to PM_{2.5} has been associated with adverse respiratory outcomes, including asthma and COPD exacerbation [5], as well as

adverse cognitive effects in children, such as decreased academic performance on standardized tests [6].

The health effects of wildfire-specific $PM_{2.5}$ are less well understood than all-source $PM_{2.5}$, as estimates of wildfire-specific $PM_{2.5}$ are less consistent than estimates of total ambient $PM_{2.5}$ [7]. In order to better evaluate the health effects of wildfire-specific $PM_{2.5}$, it is therefore important to understand the strength of correlation between wildfire activity in a region and the ambient $PM_{2.5}$ measured by ground monitors.

In this study, we examine the relationship between wildfires and $PM_{2.5}$ in Los Angeles County by correlating the number of fires and fire radiative power (FRP) detected by the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the NOAA-21 satellite with ground monitor $PM_{2.5}$ measurements from the U.S. Environmental Protection Agency's Air Quality System during 2025. In this way, the percent variation in ambient $PM_{2.5}$ associated with wildfire activity can be estimated using the coefficient of determination (R^2). We also analyze Jakarta, Indonesia, another city that experiences wildfire seasons and is exposed to ambient $PM_{2.5}$ levels that consistently exceed international air quality standards [8]. Using ground monitored $PM_{2.5}$ data from OpenAQ, we examine whether similar relationships between wildfire activity, FRP, and ambient $PM_{2.5}$ can be observed in Jakarta during 2025, allowing us to compare whether these relationships are consistent across different regions.

Methods

All fire data were obtained from NASA's Fire Information for Resource Management System (FIRMS), using the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the NOAA-21 satellite. NASA FIRMS provides 375-m VIIRS active-fire detections from NOAA-21, including the geographic coordinates and fire radiative power (FRP) of each detection. [9] All available VIIRS fire detections within a bounding box encompassing Los Angeles County were downloaded for 2025. Each detection contains the latitude and longitude of the detected fire pixel, as well as its FRP. Fire radiative power (FRP), measured in megawatts (MW), represents the rate at which radiant energy is released by an actively burning fire. FRP has been shown to be strongly related to the rate of biomass combustion and can therefore serve as an indicator of fire intensity and potential biomass-burning emissions [10].

EPA ground-monitor $PM_{2.5}$ daily averages were downloaded from the U.S. Environmental Protection Agency's AirData database, which provides 24-hour $PM_{2.5}$ concentrations in micrograms per cubic meter ($\mu g/m^3$) [11]. Eight total $PM_{2.5}$ monitors were identified within Los Angeles County. Three monitors were isolated for further analysis due to their proximity to the January 2025 Palisades and Eaton fires. Each monitor provided a daily average $PM_{2.5}$ concentration in micrograms per cubic meter ($\mu g/m^3$). For Indonesia, data from five $PM_{2.5}$

ground monitors within Jakarta were obtained through the OpenAQ API [12]. The daily average PM_{2.5} concentration and geographic coordinates of each monitor were collected.

For both the Los Angeles and Jakarta ground-monitor datasets, some monitors had missing days of observations. Therefore, the final analysis was performed on monitor-days, where a daily PM_{2.5} average for a specific monitor on a specific day of 2025 is treated as a unique value to correlate with wildfire activity.

The distance between each fire detection and each PM_{2.5} monitor was calculated using the Haversine formula, which calculates the great-circle distance between two points on the Earth's surface from their latitude and longitude coordinates [13]. The resulting distance was expressed in kilometers. For each monitor-day, three measures of nearby wildfire activity were calculated using only fires within 25 km of the monitor: number of fire detections, total FRP, and distance-weighted FRP. Distance-weighted FRP was calculated in two ways. The first used inverse-distance weighting, in which each fire's FRP was divided by its distance from the monitor:

$$1) \quad \sum \frac{FRP_i}{d_i}$$

The second used inverse-square-distance weighting:

$$2) \quad \sum \frac{FRP_i}{d_i^2}$$

FRP_i represents the FRP of a detected fire and d_i represents its distance in kilometers from the PM_{2.5} monitor. This calculation is performed on all fires within a radius of 25 km from the monitor to give greater influence to fires located closer to the monitor.

Results

Table 1. Summary of simple correlation results between wildfires and PM_{2.5} for all Los Angeles EPA PM_{2.5} monitors.

Wildfire metric correlated with PM2.5	p-value	R value	R squared
Total FRP	7.22E-25	0.2729	0.0745
Distance weighted FRP (inverse)	1.18E-21	0.254	0.0645
Distance weighted FRP (squared inverse)	6.17E-17	0.223	0.0497
Number of fire detections	3.02E-40	0.3475	0.1207

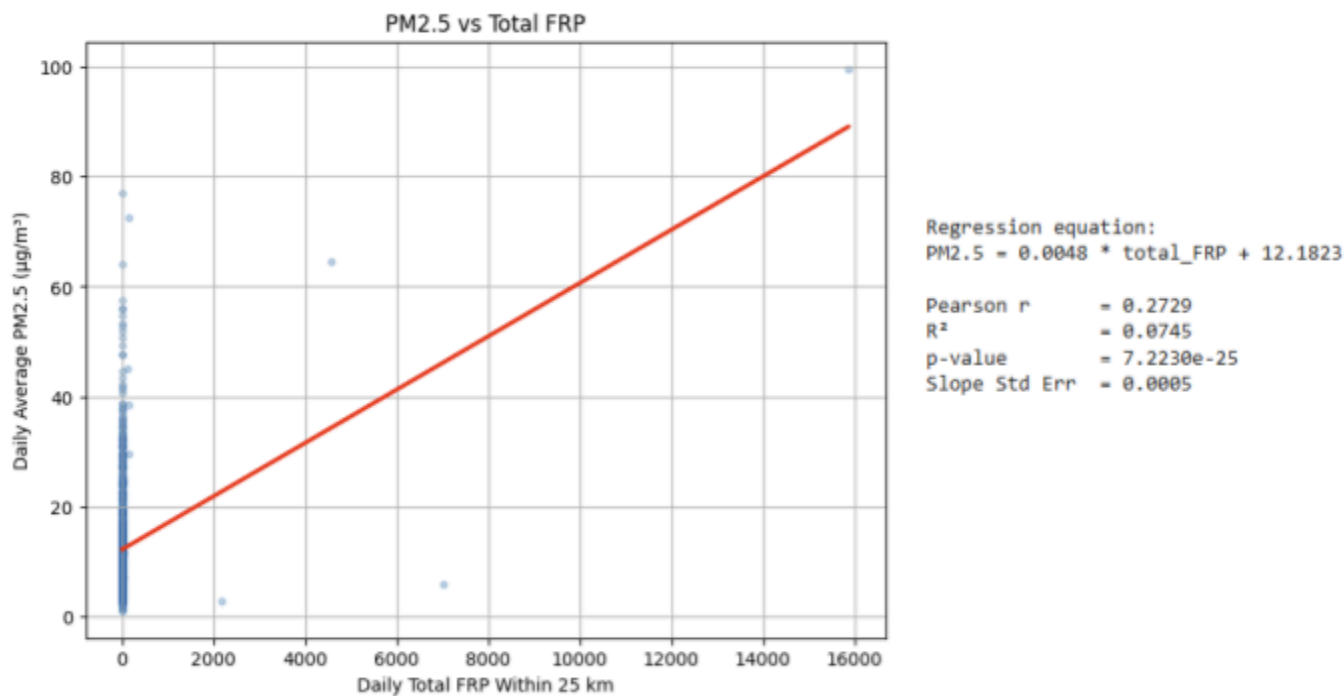


Figure 1. Daily average $PM_{2.5}$ concentration as a function of total FRP within a 25 km radius of each monitor for all monitor-days in Los Angeles County during 2025.

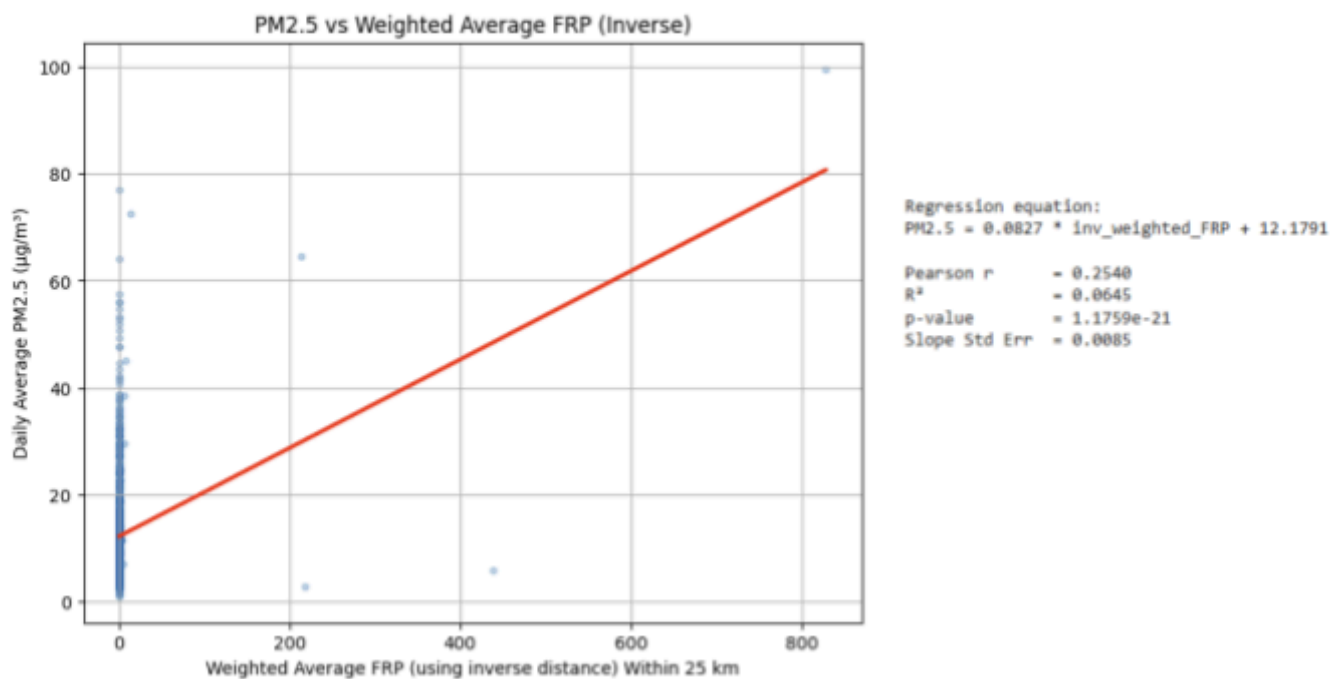


Figure 2. Daily average $PM_{2.5}$ concentration as a function of inverse distance-weighted FRP within a 25 km radius of each monitor for all monitor-days in Los Angeles County during 2025.

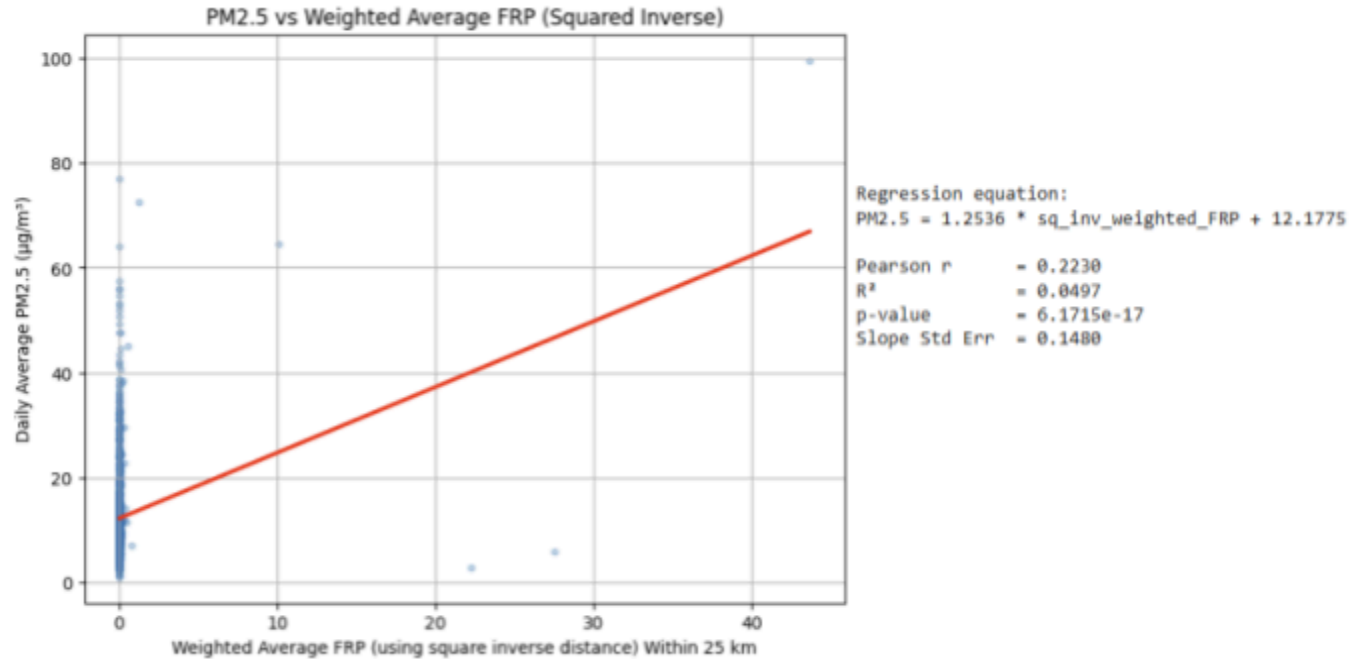


Figure 3. Daily average $PM_{2.5}$ concentration as a function of inverse-square distance-weighted FRP within a 25 km radius of each monitor for all monitor-days in Los Angeles County during 2025.

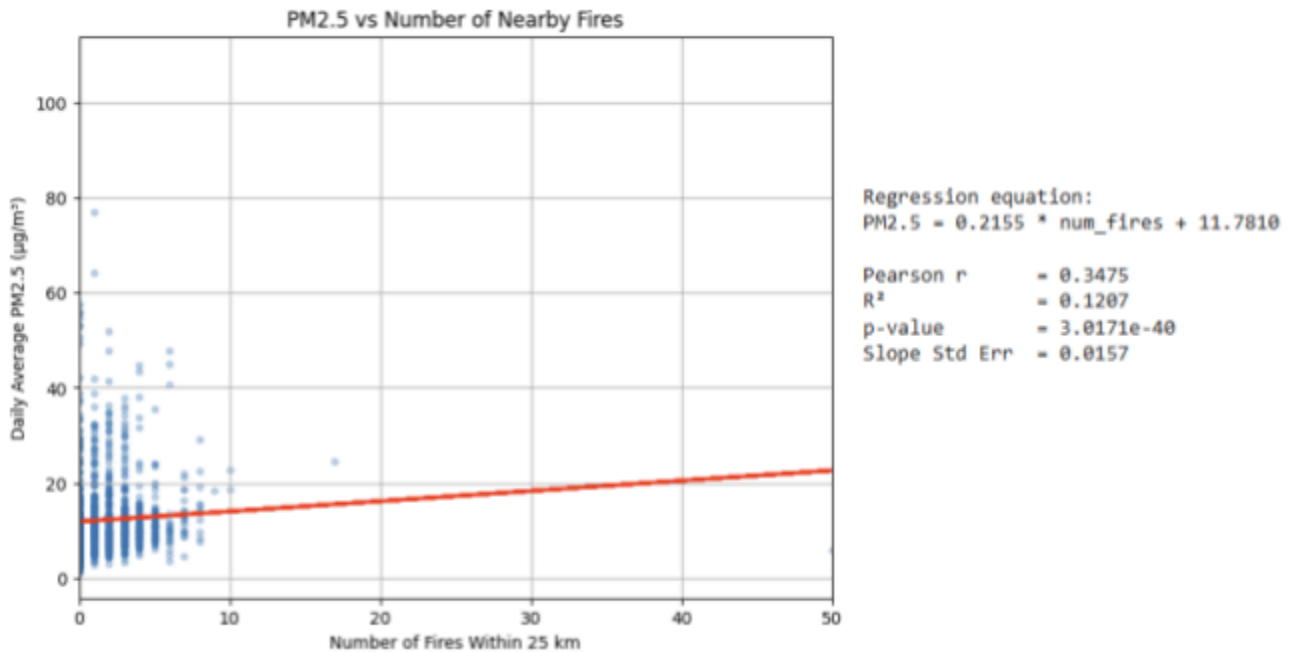


Figure 4. Daily average $PM_{2.5}$ concentration as a function of total fire detections within a 25 km radius of each monitor for all monitor-days in Los Angeles County during 2025.

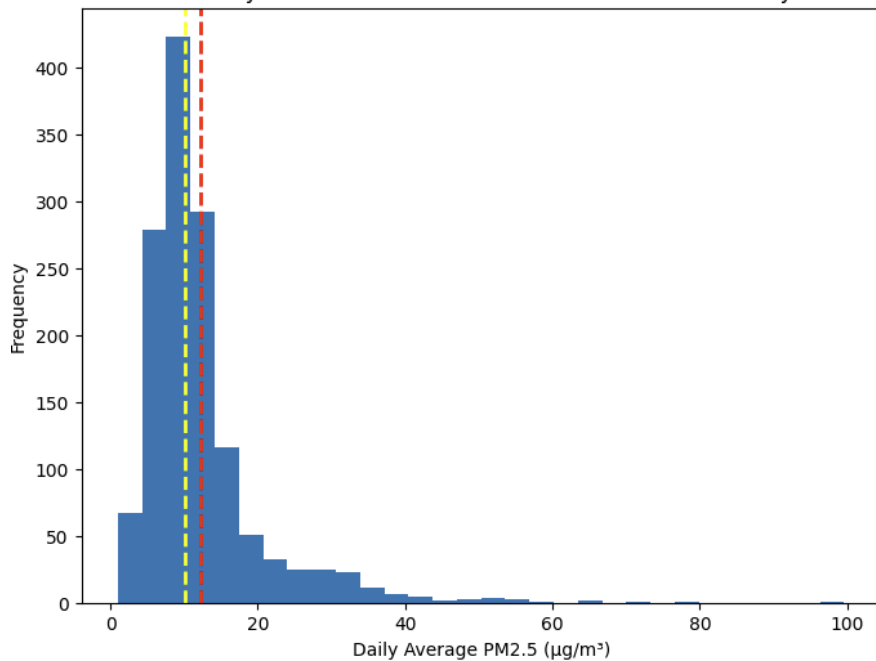


Figure 5. Distribution of daily average PM_{2.5} concentrations for each monitor-day for all PM_{2.5} monitors across Los Angeles County during 2025. The histogram shows a right skewed distribution with the mean at 12.3 µg/m³ (red) and median at 10.2 µg/m³ (yellow).

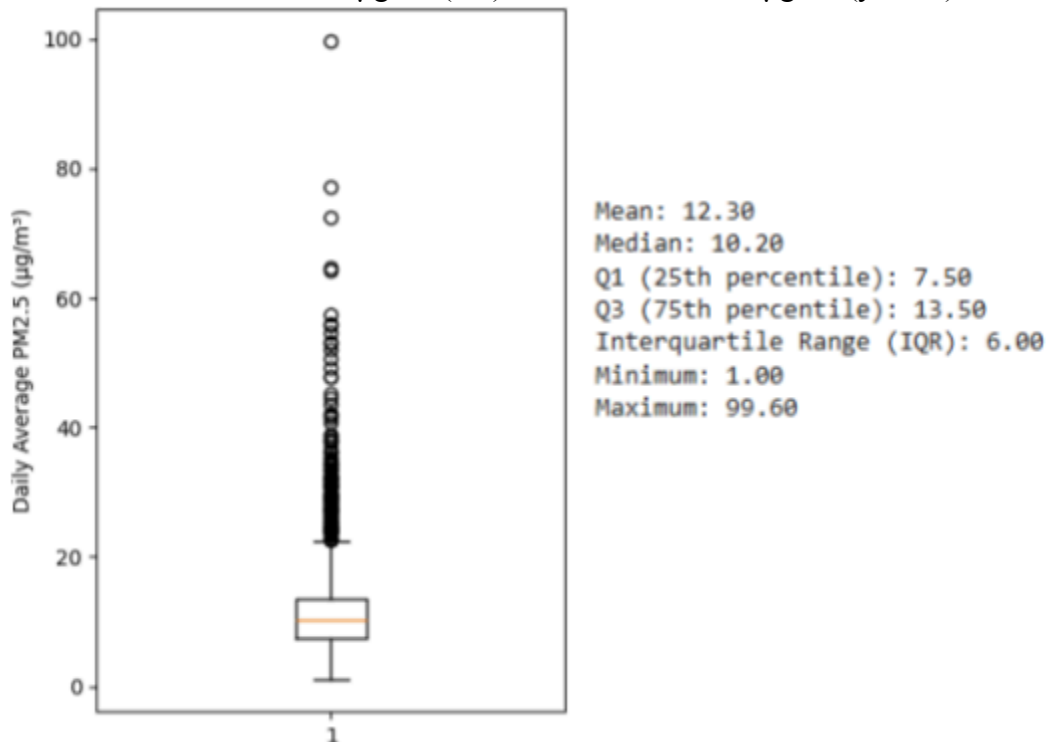


Figure 6. Boxplot of daily average PM_{2.5} concentrations for each monitor-day for all PM_{2.5} monitors across Los Angeles County during 2025.

Table 2. Summary of simple correlation results between wildfires and PM_{2.5} for three Los Angeles EPA PM_{2.5} monitors closest to the Palisades fires.

PM2.5 correlated with	p-value	R value	R squared
Number of fire detections	2.21E-36	0.4985	0.2485
Total FRP	1.61E-23	0.4057	0.1646
Distance weighted FRP (inverse)	2.13E-20	0.378	0.1429
Distance weighted FRP (squared inverse)	7.32E-16	0.3324	0.1105

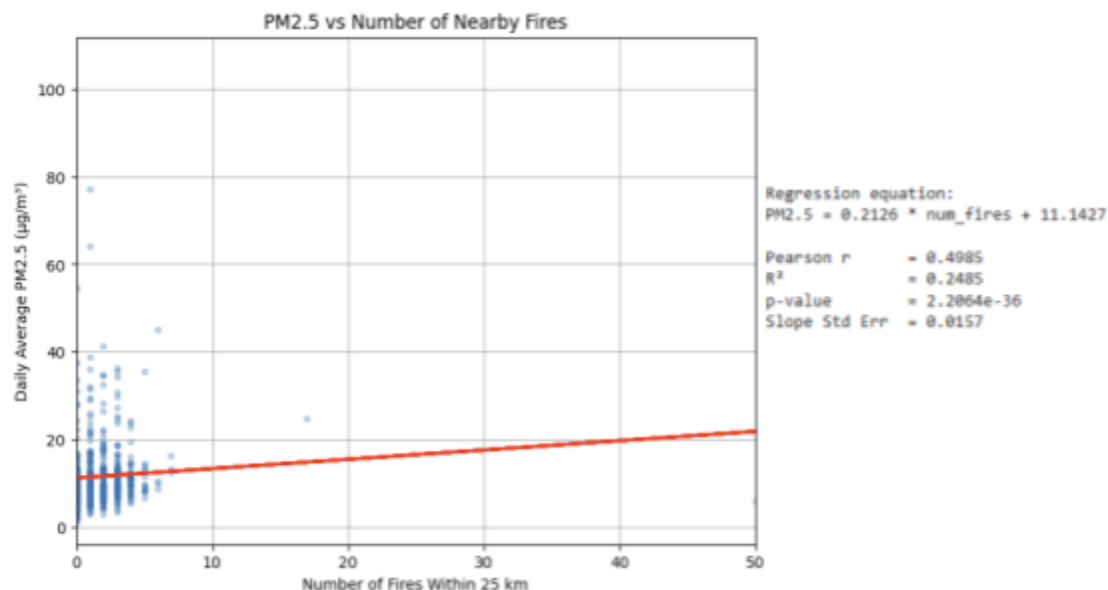


Figure 7. For three monitors closest to the Palisades fires, daily average PM_{2.5} concentrations are plotted as a function of total fire detections within a 25 km radius of each monitor. All monitor-days for 2025 are plotted.

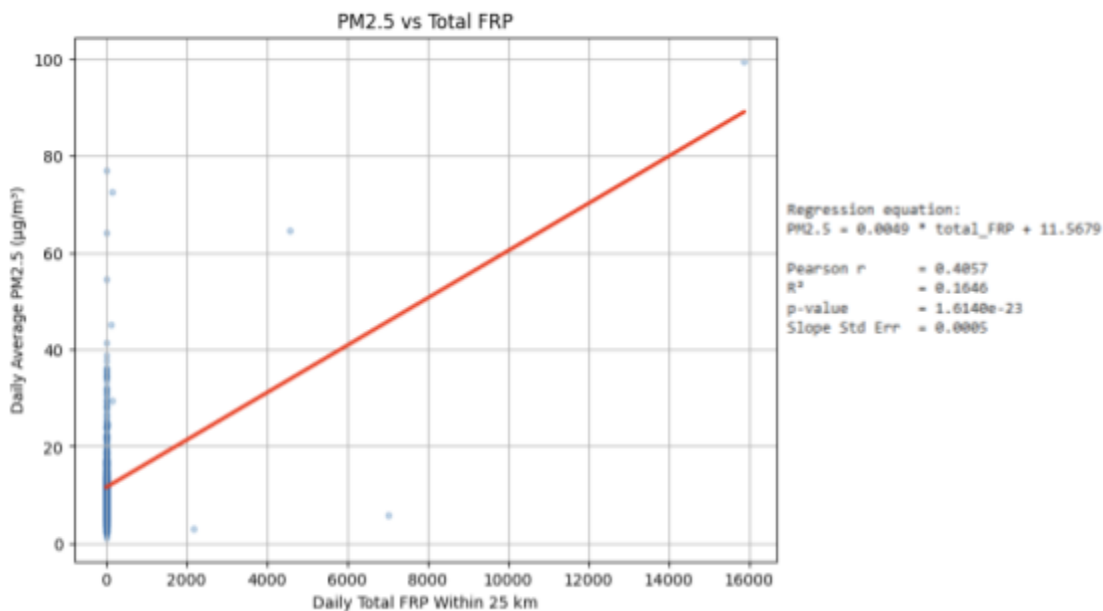


Figure 8. For three monitors closest to the Palisades fires, daily average $\text{PM}_{2.5}$ concentrations are plotted as a function of total FRP within a 25 km radius of each monitor. All monitor-days for 2025 are plotted.

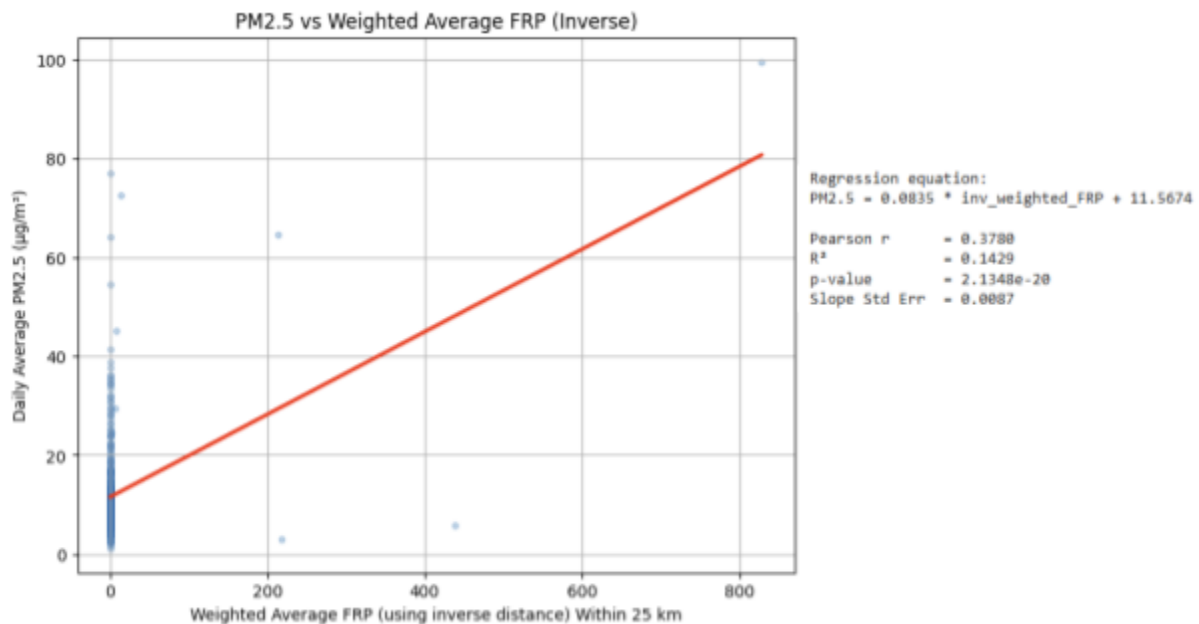


Figure 9. For three monitors closest to the Palisades fires, daily average $\text{PM}_{2.5}$ concentrations are plotted as a function of inverse distance-weighted FRP within a 25 km radius of each monitor. All monitor-days for 2025 are plotted.

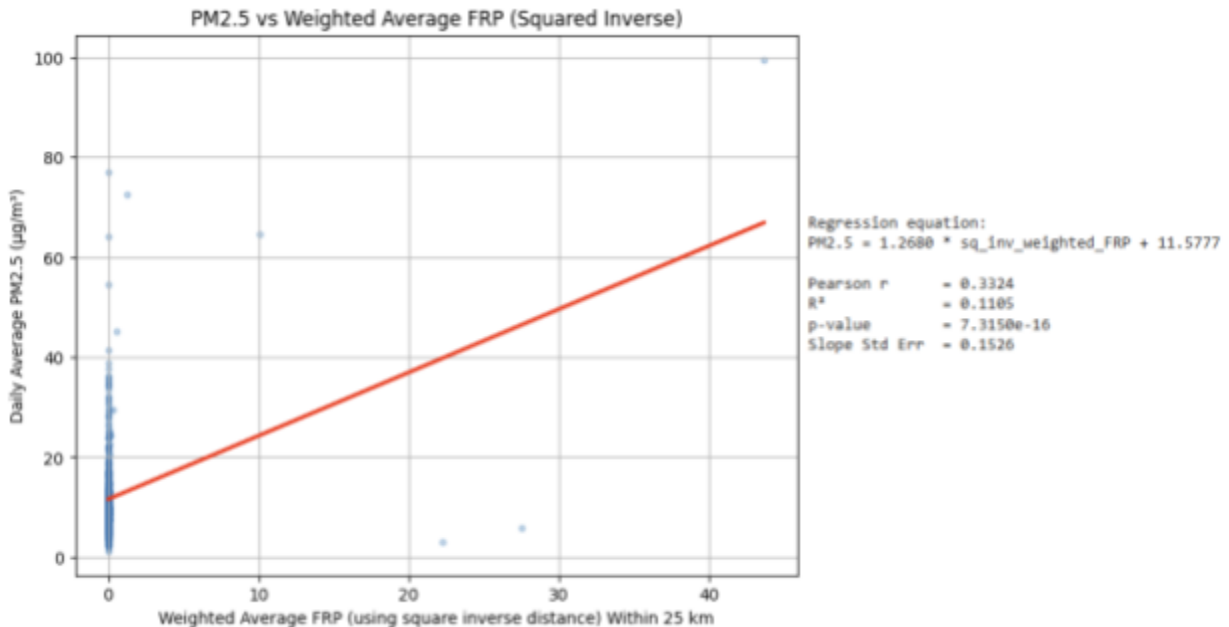


Figure 10. For three monitors closest to the Palisades fires, daily average $\text{PM}_{2.5}$ concentrations are plotted as a function of inverse-squared distance-weighted FRP within a 25 km radius of each monitor. All monitor-days for 2025 are plotted.

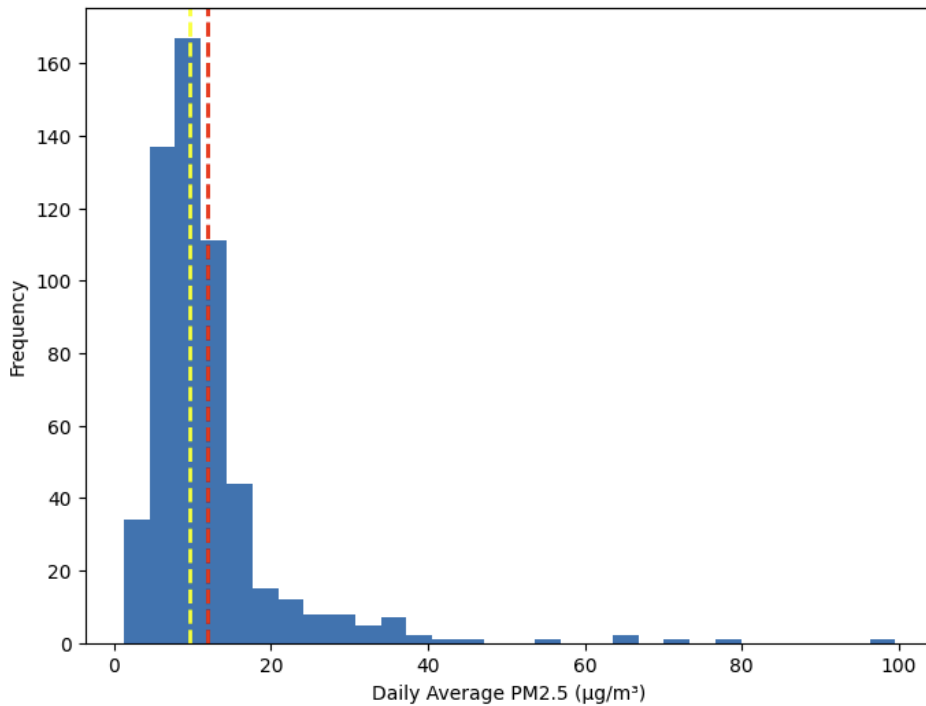


Figure 11. Distribution of daily average PM_{2.5} concentrations on each monitor-day for the three PM_{2.5} monitors closest to the Palisades fires during 2025. The histogram shows a right skewed distribution with the mean at 11.84 µg/m³ (red) and median at 9.70 µg/m³ (yellow).

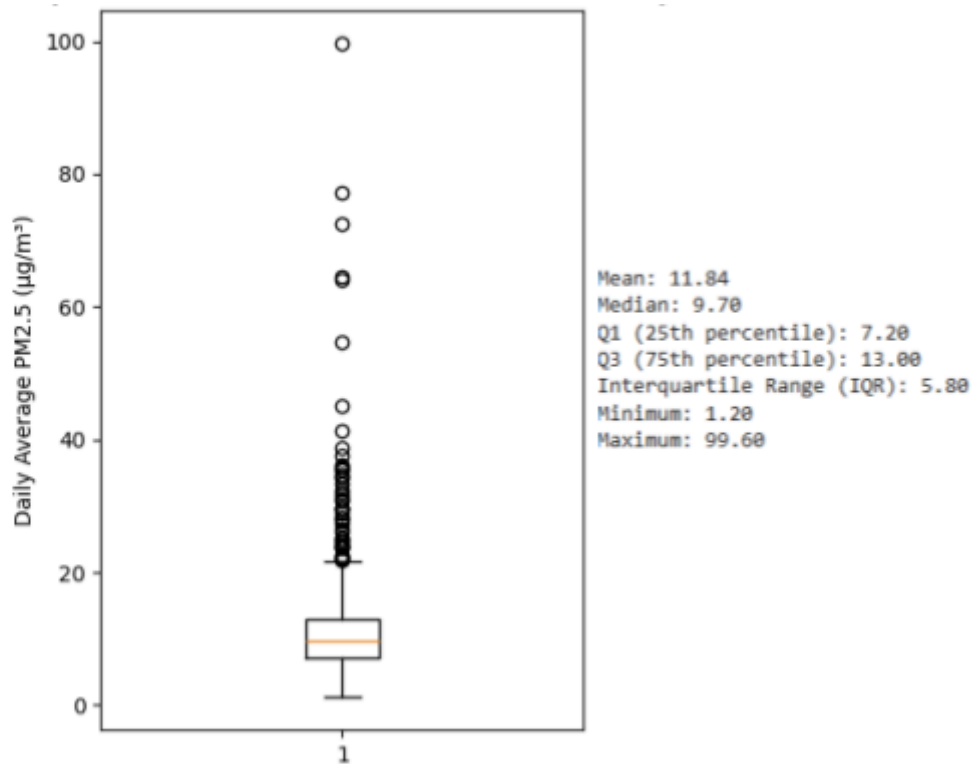


Figure 12. Boxplot of daily average PM_{2.5} concentrations on each monitor-day for the three PM_{2.5} monitors closest to the Palisades fires during 2025.

Table 3. Summary of simple correlation results between wildfires and PM_{2.5} for five Jakarta OpenAQ PM_{2.5} monitors.

PM2.5 correlated with	p-value	R value	R squared
Number of fire detections	8.21E-08	0.1909	0.0364
Total FRP	1.81E-05	0.1532	0.0235
Distance weighted FRP (inverse)	5.20E-02	0.0697	0.0049
Distance weighted FRP (squared inverse)	4.71E-01	-0.0259	0.0007

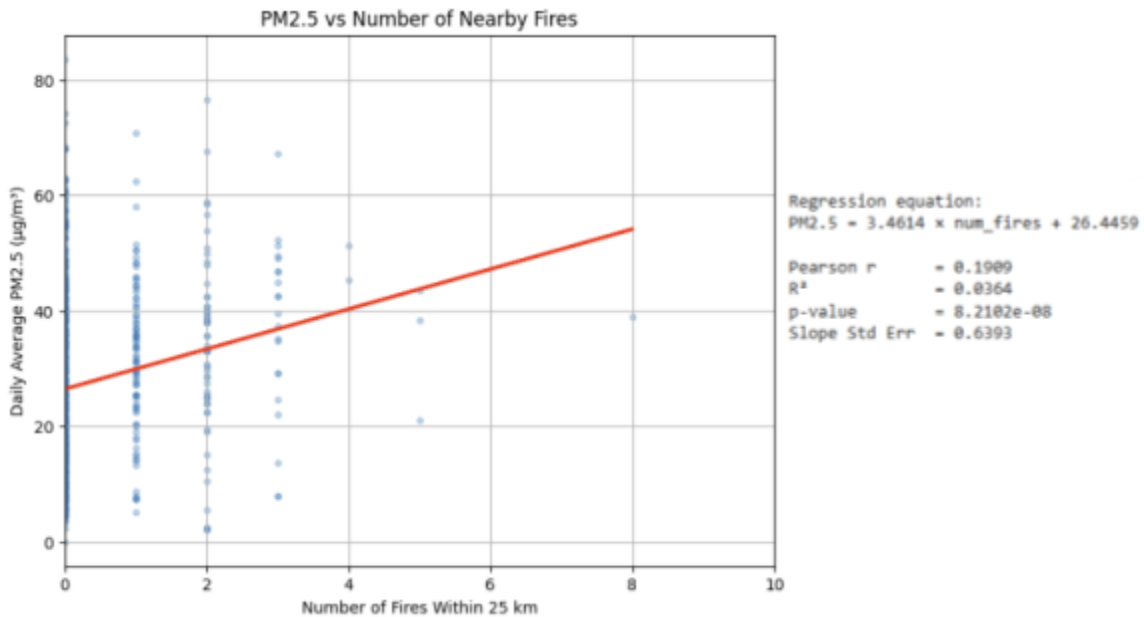


Figure 13. Daily average PM_{2.5} concentration as a function of total number of fire detections within a 25 km radius of each monitor for all monitor-days in Jakarta during 2025.

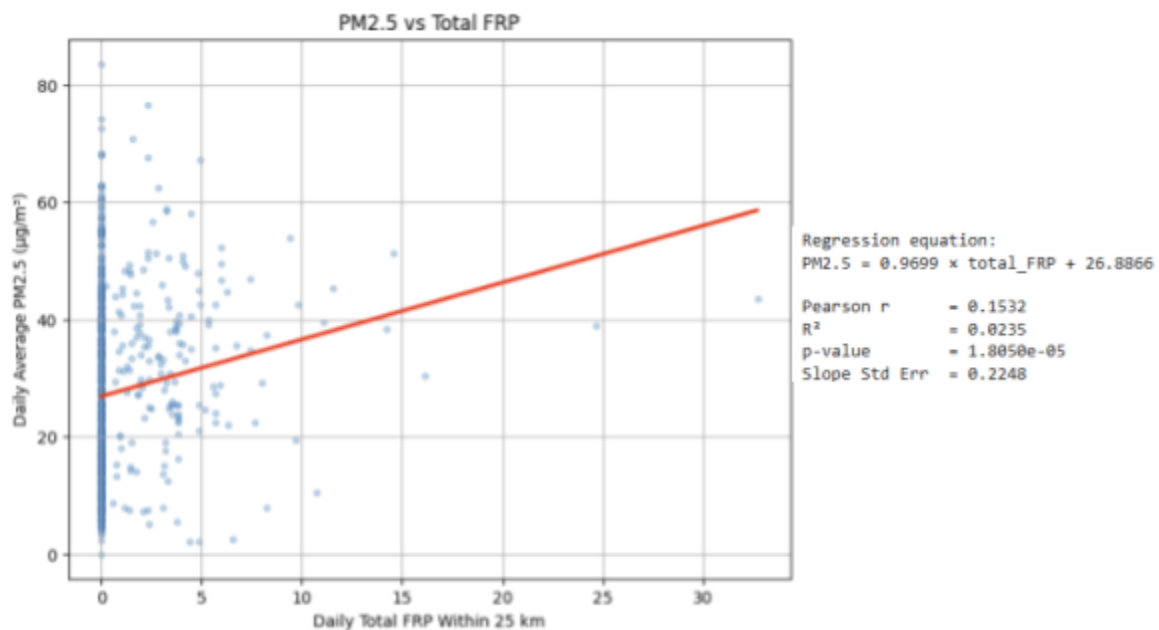


Figure 14. Daily average PM_{2.5} concentration as a function of total FRP within a 25 km radius of each monitor for all monitor-days in Jakarta during 2025.

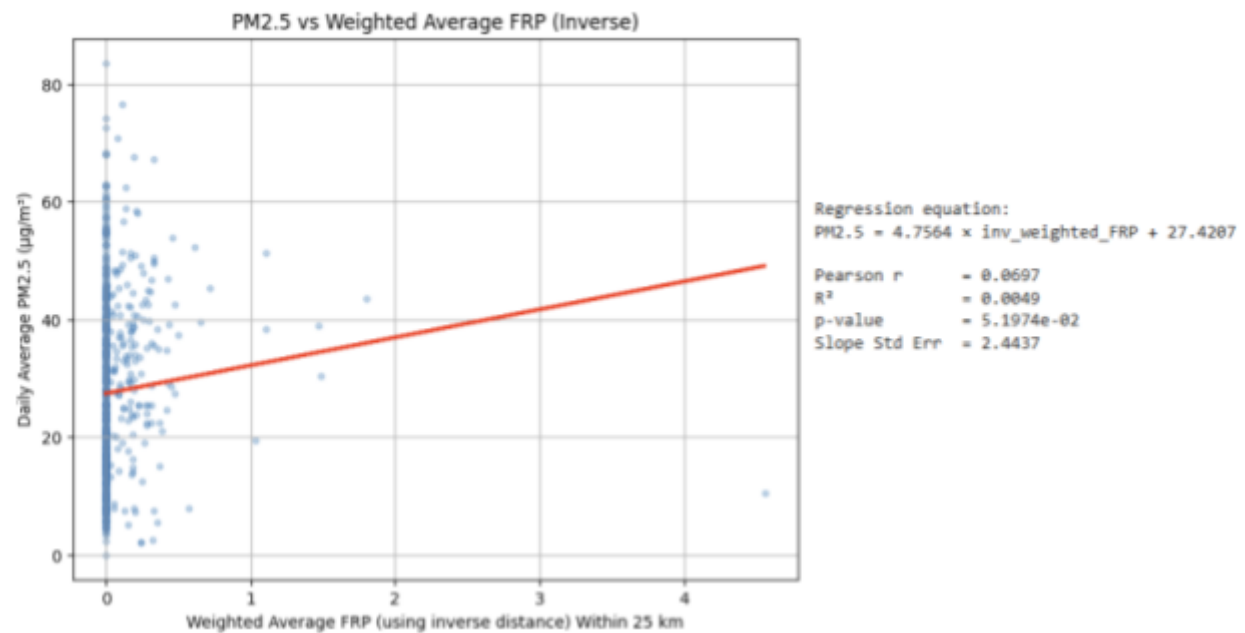


Figure 15. Daily average PM_{2.5} concentration as a function of inverse distance-weighted FRP within a 25 km radius of each monitor for all monitor-days in Jakarta during 2025.

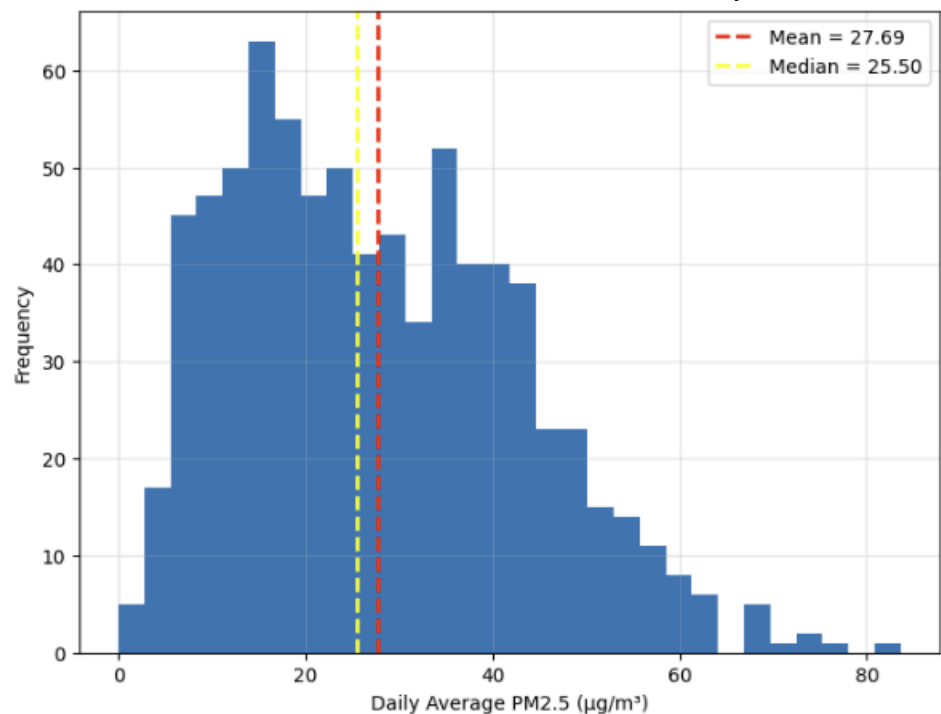


Figure 16. Distribution of daily average PM_{2.5} concentrations for each monitor-day for all PM_{2.5} monitors across Jakarta during 2025. The histogram shows a right skewed distribution with the mean at 27.69 µg/m³ (red) and median at 25.50 µg/m³ (yellow).

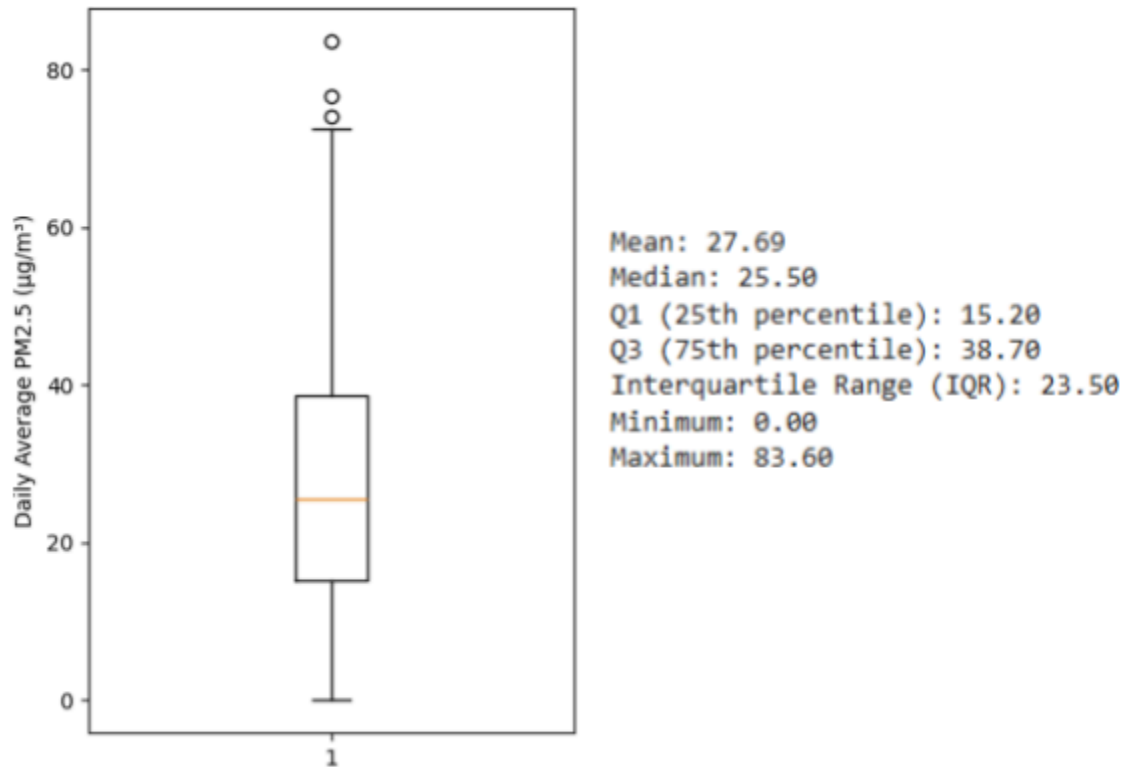


Figure 17. Boxplot of daily average $PM_{2.5}$ concentrations for each monitor-day for all $PM_{2.5}$ monitors across Jakarta during 2025.

Discussion

In both Los Angeles and Jakarta, the number of detected fires within a 25 kilometer radius explained the greatest proportion of variation in daily average ambient $PM_{2.5}$. Although FRP, which is proportional to combustion and thus intensity of the fires, was expected to yield the strongest correlation with $PM_{2.5}$, total FRP and both distance-weighted FRP metrics produced lower R^2 values than the number of detected fires (Tables 1, 2, 3). Furthermore, considering the fires' distance from the monitor using an inverse and inverse squared model did not improve the correlation as compared to total FRP alone (Fig. 1, 2, 3). These trends were observed for both Los Angeles and Jakarta, suggesting that the number of detected fires may have been a more informative indicator of local fire activity than measures of fire intensity in this dataset.

The correlation between number of detected fires and ambient $PM_{2.5}$ was particularly pronounced among the three monitors closest to the Palisades fires, located at 1630 North Main Street, 18330 Gault Street, and 752 South Wilson Avenue. For these monitors, the number of detected fires within a 25 km radius for each monitor explained 24.8% of the variation in daily average $PM_{2.5}$ (Fig. 4). While the regression analysis performed cannot indicate causality, it suggests that wildfire activity was one of several contributors to daily $PM_{2.5}$ concentrations.

The differences in correlation strength between Los Angeles and Jakarta are likely because the two regions may have different main sources of ambient PM_{2.5}. Jakarta exhibited higher mean and median daily average PM_{2.5} concentrations than Los Angeles and a less pronounced right skew, indicating generally higher and more consistently elevated PM_{2.5} levels (Fig. 5, 11, 16). Jakarta also displayed lower R² values and less statistical significance than Los Angeles across all PM_{2.5} correlations with wildfire metrics (Tables 1, 3). While the January 2025 fires may have contributed significantly to PM_{2.5} variation in Los Angeles, PM_{2.5} in Jakarta is likely heavily influenced by anthropogenic sources such as vehicle emissions and other urban activities. As a result, while the number of fires explained up to 24.8% of the variation in ambient PM_{2.5} in Los Angeles (Fig. 4), in Jakarta the number of fires explained 3.64% of the variation in ambient PM_{2.5} (Fig. 13).

The relatively limited contribution of detected fires in Jakarta may also reflect differences in fire activity during 2025. Although Indonesia experienced forest and land fires during the year, national fire activity was substantially lower than in recent years, as the Indonesian Ministry of Forestry reported a 43.2% decrease from 2024 in hectares affected by forest and land fires [14]. Moreover, major fire-control efforts during the 2025 dry season focused on fire-prone provinces including Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, and South Kalimantan rather than Jakarta [15]. Thus, the fires detected near Jakarta monitors may have represented a relatively small component of the region's overall PM_{2.5} burden.

Limitations

Several limitations should be considered in the interpretation of the study's results. First, simple correlation between ambient PM_{2.5} and wildfire metrics does not take into account the weather conditions of that day, such as temperature, precipitation, and wind. These factors can affect whether and how much smoke from a given fire reaches a monitoring station. Creating a multivariable model of daily weather conditions can provide a more accurate estimate of how much each wildfire's smoke contributes to ambient PM_{2.5} concentrations.

Second, using ground monitor measurements of PM_{2.5} as opposed to satellite modeled PM_{2.5} limits the geographic coverage of the analysis. Although all available EPA monitors and all available OpenAQ monitors were analyzed in the dataset, the analysis was based on only eight monitoring stations in Los Angeles and five in Jakarta. Additionally, no individual monitoring station recorded a daily average PM_{2.5} measurement for every day of 2025, resulting in incomplete temporal coverage.

Finally, this study defined a 25 kilometer radius around each monitoring station to focus on fires most likely to contribute to measured PM_{2.5} concentrations. However, this radius may have excluded more distant fires whose smoke was transported to the monitoring locations through wind. Expanding the radius to 100 kilometers may capture a greater proportion of relevant fire

activity and potentially improve the correlation between fire activity and ambient PM_{2.5}. A 100 kilometer radius was similarly used in a previous study that developed a predictive model of PM_{2.5} using ground-monitor measurements and FRP data [16].

Areas of Future Study

This research was designed as a Phase I study to establish the relationship between wildfire activity and ambient PM_{2.5} before investigating the health effects of wildfire-specific PM_{2.5} exposure in Los Angeles and Indonesia during 2025. Because wildfire activity explained a greater proportion of the variation in ambient PM_{2.5} in Los Angeles than in Jakarta, further investigation of the potential health effects of wildfire-specific PM_{2.5} exposure in Los Angeles is particularly relevant.

Future research could improve the correlation between wildfire activity and ambient PM_{2.5} by incorporating daily meteorological conditions, including wind speed and direction, precipitation, and temperature, which influence the transport of wildfire smoke. Furthermore, comparing wildfires of multiple radii in addition to 25 kilometers could identify the distance at which wildfire metrics have the strongest relationship with ambient PM_{2.5}. In Indonesia, conducting a similar analysis using monitoring stations located in provinces with greater fire activity may provide a stronger association between wildfire activity and ambient PM_{2.5} and yield higher R₂ values. These improvements could provide a more precise estimate of wildfire-specific PM_{2.5} exposure for subsequent research examining its potential health effects.

References

1. Yue, Xu, Loretta J. Mickley, and Jennifer A. Logan. "Projection of Wildfire Activity in Southern California in the Mid-21st Century." *Climate Dynamics*, vol. 43, nos. 7–8, 2014, pp. 1973–1991. <https://doi.org/10.1007/s00382-013-2022-3>
2. California Department of Forestry and Fire Protection. "Palisades Fire." *CAL FIRE*, 7 Jan. 2025, www.fire.ca.gov/incidents/2025/1/7/palisades-fire
3. Aguilera, Ricardo, et al. "Wildfire Smoke Impacts Respiratory Health More Than Fine Particles from Other Sources: Observational Evidence from Southern California." *Nature Communications*, vol. 12, 2021, article 1493. <https://doi.org/10.1038/s41467-021-21708-0>
4. American Lung Association. *State of the Air 2025*. American Lung Association, 2025, www.lung.org/research/sota
5. Aguilera, Ricardo, et al. "Health Effects of Wildfire Smoke Exposure." *Annual Review of Medicine*, vol. 75, 2024, pp. 277–292. <https://doi.org/10.1146/annurev-med-052422-020909>
6. Wen, Jeff, and Marshall Burke. "Lower Test Scores from Wildfire Smoke Exposure." *Nature Sustainability*, vol. 5, 2022, pp. 947–955. <https://doi.org/10.1038/s41893-022-00956-y>

7. Orr, Ava, et al. "A State of the Science Review of Wildfire-Specific Fine Particulate Matter Data Sources, Methods, and Models." *Environmental Health Perspectives*, vol. 133, no. 6, 2025, article 066. <https://doi.org/10.1289/EHP15672>
8. Kurniawan, et al. "Impacts of Air Pollution on Health and Cost of Illness in Jakarta, Indonesia." *International Journal of Environmental Research and Public Health*, vol. 20, no. 4, 2023, article 2916. <https://doi.org/10.3390/ijerph20042916>
9. National Aeronautics and Space Administration. "FIRMS: Download." *Fire Information for Resource Management System*, NASA, firms.modaps.eosdis.nasa.gov/download/. Accessed 12 July. 2026.
10. Wooster, Martin J., et al. "Retrieval of Biomass Combustion Rates and Totals from Fire Radiative Power Observations: FRP Derivation and Calibration Relationships between Biomass Consumption and Fire Radiative Energy Release." *Journal of Geophysical Research: Atmospheres*, vol. 110, no. D24, 2005, article D24111. <https://doi.org/10.1029/2005JD006318>
11. U.S. Environmental Protection Agency. "AirData: Download Files." *United States Environmental Protection Agency*, aqsweb.airdata/download_files.html. Accessed 12 July. 2026.
12. OpenAQ. "About the API." *OpenAQ*, docs.openaq.org/about/about
13. Karney, Charles F. F. "Algorithms for Geodesics." *Journal of Geodesy*, vol. 87, 2013, pp. 43–55. <https://doi.org/10.1007/s00190-012-0578-z>
14. Antara News. "Turun Drastis, Menhut Sebut Karhutla Tercatat 213 Ribu Ha pada 2025." *ANTARA News*, 2025, <https://www.antaranews.com/berita/5170705/turun-drastis-menhut-sebut-karhutla-tercatat-213-ribu-ha-pada-2025>
15. Antara News. "Six Priority Provinces' Fires Are under Control: BNPB." *ANTARA News*, 2025, <https://en.antaranews.com/news/372909/six-priority-provinces-fires-are-under-control-bnpb>
16. Marsha, Amy, and Narasimhan K. Larkin. "A Statistical Model for Predicting PM_{2.5} for the Western United States." *Journal of the Air & Waste Management Association*, vol. 69, no. 10, 2019, pp. 1215–1229. <https://doi.org/10.1080/10962247.2019.1640808>