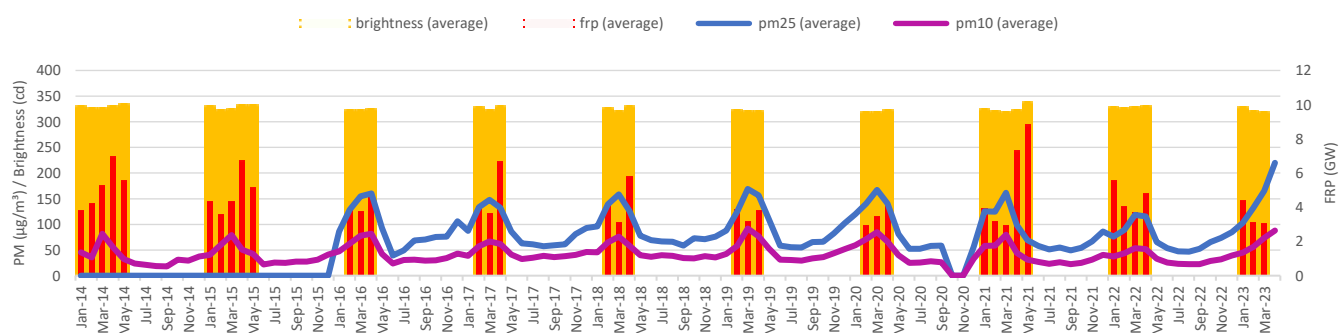


# Biomass Burning Firing Up Urban Pollution in Chiang Mai

It is no mystery that the source of Chiang Mai's seasonal pollution stems from agricultural burning activities. Annually, the city and the northern region of Thailand are engulfed in an unhealthy cloud of pollutants. Burning leftover vegetative materials in the open is a frequent practice because it is inexpensive. It is used to reduce crop residue, stimulate yield, control diseases, reduce unwanted plant species, or maintain soil productivity. Being inexpensive in terms of monetary and time cost, it is a primary tool for farmers who seek to maximize their profit and maintain their already limited livelihood opportunities.

Burning of vegetative residue is associated with respiratory health complications, increasing premature death.<sup>1</sup> Chiang Mai has recorded yearly increases in patients seeking medical assistance for respiratory and other pollution-associated diseases.<sup>2</sup> As voices grow louder regarding the yearly haze, public discourse has sought to blame agricultural burning on neighbouring countries.<sup>3</sup> While neighbouring countries may also employ agricultural burning, the fire hotspot data presented in this paper is based on geographical coordinates pinpointing provinces within Thailand's own borders, specifically Chiang Mai city's surrounding provinces: Chiang Mai (province), Lamphun, and Lampang.

Figure 1: Monthly averages of PM<sub>2.5</sub>, PM<sub>10</sub>, FRP, brightness of fire, January 2014 to March 2023.



Note: No data for PM<sub>2.5</sub> prior to December 2015; no data for PM<sub>2.5</sub> and PM<sub>10</sub> for October 2020.

Data source: Particulate Matter: Air4Thai. Access: <http://air4thai.pcd.go.th/webV3/#/History>. Hotspots: NASA Fire Information for Resource Management System (FIRMS). Access: <https://firms.modaps.eosdis.nasa.gov/>

The presented figure above examines registered hotspots and air pollution over the past nine years, from 2014 to 2023. It combines data on air pollution measurements for Chiang Mai city, Thailand, and registered hotspots in the surrounding provinces of Chiang Mai (province), Lamphun, and Lampang. The measurements displayed include particulate matter (PM) 2.5 and PM<sub>10</sub> (particles smaller than 2.5 and 10 micrometres per cubic meter, respectively), fire brightness levels in candela (cd), and Fire Radiative Power in gigawatts (GW). Each measurement is the average of registered information for each month.

## Air quality reaches health threatening levels

Air pollution levels measured for PM<sub>2.5</sub> and PM<sub>10</sub> show cyclic trends.<sup>4</sup> PM<sub>2.5</sub> measurements typically range between 50 µg/m<sup>3</sup> and 80 µg/m<sup>3</sup> from May to October, with the lowest values observed between June and August. The average for the May to October period is about 60 µg/m<sup>3</sup>. PM<sub>10</sub> measurements typically around 30 µg/m<sup>3</sup> between May and November, which is also its average, show little variation. PM<sub>2.5</sub> levels can be observed to increase from November

<sup>1</sup> He, Liu, and Zhou, 2020. Straw burning, PM<sub>2.5</sub>, and death: Evidence from China. In: Journal of Development Economics Volume 145, 102468. Access: <https://www.sciencedirect.com/science/article/abs/pii/S0304387820300432>

<sup>2</sup> Varapongpisan, T. et. al., 2022. Association between out-patient visits and air pollution in Chiang Mai, Thailand: Lessons from a unique situation involving a large data set showing high seasonal levels of air pollution. In: PLoS One. 2022; 17(8): e0272995. Access: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9387779/>; Bangkok Post, 2024. Lung cancer, PM<sub>2.5</sub> deaths surge in the North. Bangkok Post, 7 Apr 2024. Access: <https://www.bangkokpost.com/thailand/general/2772351/lung-cancer-pm2-5-deaths-surge-in-the-north> ; Jainonthee, C., 2022. Trop. Med. Infect. Dis. 2022, 7(11), 341. Access: <https://doi.org/10.3390/tropicalmed7110341>

<sup>3</sup> Marks, D., 2021. Transboundary haze control lacks political will. Bangkok Post, 13 Mar 2021. Access: <https://www.bangkokpost.com/opinion/opinion/2082923/transboundary-haze-control-lacks-political-will>

<sup>4</sup> PM<sub>2.5</sub>: Particles with an aerodynamic diameter less than or equal to a nominal 2.5 micrometers, as a result of burning combustible materials and in particular organic matter; PM<sub>10</sub>: Particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers primarily but not exclusively attributed to dust particles.

and December onwards until April and occasionally into May, ranging widely between 80  $\mu\text{g}/\text{m}^3$  to over 200  $\mu\text{g}/\text{m}^3$ , with a nine-year average of 119  $\mu\text{g}/\text{m}^3$  for those months. Individual measurements can reach PM2.5 levels of 291  $\mu\text{g}/\text{m}^3$ , as seen in March 2023, which is just below the 'hazardous' threshold of 300  $\mu\text{g}/\text{m}^3$ .

PM10 measurements follow a similar trend, typically ranging between 40  $\mu\text{g}/\text{m}^3$  and 90  $\mu\text{g}/\text{m}^3$  for the same time periods. The nine-year average for November to May of each year is 54  $\mu\text{g}/\text{m}^3$ . Although individual spikes in particulate matter emissions occur and exceed average levels, it is noticeable that the average levels for both PM2.5 and PM10 double from one observation period to the next each year.

### Fire Brightness and Radiative Power

Satellites equipped with thermal sensors spot and track potential fires (hotspots) from Earth's orbit. With the help of satellites, the intensity and extent of potential fires can be approximated. Two measures for this purpose are brightness and Fire Radiative Power (FRP). In layman's terms, brightness depends on the material or fuel source that is burned; it serves as an indicator to recognize similar materials serving as a fire's fuel source. The brightness of a fire also indicates the temperature at which a fire burns. The brightness itself can be influenced by whether it occurs during the day or night. However, not every fire or heat emission is visible to the human eye (or sensors equivalent to the eye), and capturing brightness alone does not indicate its size.

FRP is a complex indicator that expands on measuring the brightness of a fire by capturing infrared radiation, which means it includes wavelengths of fire not captured through brightness alone. FRP provides an indication of the extent of a fire, whereas brightness alone serves only as a measure of its intensity. For instance, a small but very bright flame might have high intensity but low extent, whereas a large fire will have both high intensity and high extent due to its vast energy output at scale. Spotting fires via either their brightness or FRP from a satellite in orbit requires them to be intense and/or extensive enough to be captured by the satellite's sensors. The size of a fire and the number of fires (or their cumulative size) increase their visibility to such a sensor.

### Chiang Mai surrounding fires parallel international forest fires

Fire hotspots in Chiang Mai province have been consistently registered over the nine-year period from January, or at the latest from February, into April (occasionally May), accounting for at least a three to four-month period. As the data on registered hotspots is based on satellite information, it is likely that individual fires occur in the months before and after each period but to a lesser extent, proverbially 'flying under the radar'. This is indicated by the elevated pollution levels in December. Across these nine years, the brightness has been notably consistent at around 328 cd, with January and May tending to show marginally higher brightness levels, and thus higher intensity. May, in particular, indicates higher intensity with an average brightness of 334 cd, compared to the lowest monthly average consistently observed in March at about 324 cd.

The FRP follows a similar trend, with noticeable peaks in April and/or May. The average FRP across the years and months stands at 4.7 GW, with monthly averages reaching peaks of between 7 GW and almost 9 GW. While these average peaks represent a 50% to nearly 100% increase compared to the overall average, individual hotspots have frequently been registered at over 100 GW, reaching nearly 300 GW. These individual peaks are comparable to wildfires registered in forests in Spain and France<sup>5</sup> or Australia<sup>6</sup>. Including the average FRPs for Chiang Mai province are comparable to wildfire incidences in Australia<sup>7</sup> and forest fires in Brazil<sup>8</sup>. Though more parallels could be drawn, the realization here should be that the hotspots in Chiang Mai province are similar in intensity to regions battling natural or manmade forest fires.

### March is of highest fire extensity

The geographical scope of registered hotspots has been limited to areas in the provinces surrounding Chiang Mai city. In other words, it does not cover all potential fires in the northern region of Thailand. Nonetheless, the total number in February typically ranges between

Figure 2: Number of fire occurrences

	Jan	Feb	Mar	Apr	May
2014	211	2,597	7,949	1,244	42
2015	289	3,266	7,892	1,219	118
2016	-	1,581	4,815	6,458	-
2017	-	1,142	6,706	1,013	-
2018	-	1,874	3,389	959	-
2019	-	4,047	7,014	3,653	-
2020	-	2,938	9,442	3,365	-
2021	941	2,684	4,270	250	172
2022	382	931	966	269	-
2023	473	2,862	3,521	-	-

Data source: NASA Fire Information for Resource Management System (FIRMS). Access: <https://firms.modaps.eosdis.nasa.gov/>

<sup>5</sup> Nunes et. Al., 2023. Assessing the role played by meteorological conditions on the interannual variability of fire activity in four subregions of Iberia. International Journal of Wildland Fire 32(11) 1529-1541. Access: <https://doi.org/10.1071/WF22137>;

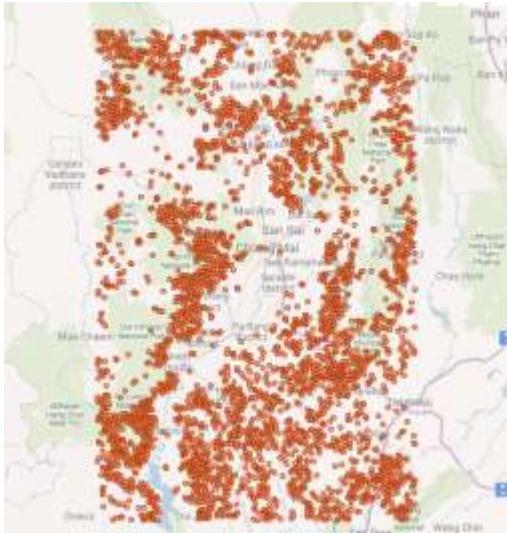
Copernicus, 2022. CAMS: monitoring extreme wildfire emissions in 2022. Copernicus, European Union Earth Observation Programme, 13th December 2022. Access: <https://atmosphere.copernicus.eu/cams-monitoring-extreme-wildfire-emissions-2022>

<sup>6</sup> Pope, et. al., 2021. Large Enhancements in Southern Hemisphere Satellite-Observed Trace Gases Due to the 2019/2020 Australian Wildfires In: Journal of Geophysical Research: Atmospheres, 126, e2021JD034892. <https://doi.org/10.1029/2021JD034892>

<sup>7</sup> Copernicus, 2019. Getting the measure of wildfires in Australia. Copernicus, European Union Earth Observation Programme, 9th February 2019. Access: <https://atmosphere.copernicus.eu/getting-measure-wildfires-australia>

<sup>8</sup> Copernicus, 2022. CAMS: monitoring extreme wildfire emissions in 2022. Copernicus, European Union Earth Observation Programme, 13th December 2022. Access: <https://atmosphere.copernicus.eu/cams-monitoring-extreme-wildfire-emissions-2022>

Figure 3: Registered hotspots around Chiang Mai city in 2023, by geographical coordinates



Data source: NASA Fire Information for Resource Management System (FIRMS). Access: <https://firms.modaps.eosdis.nasa.gov/>

about 1,000 to 4,000, and in April typically between 1,000 to 3,600, with the exception of 2016, which saw over 6,400 registered hotspots. March is the month in which the majority of activities tends to take place, typically ranging between 3,000 to nearly 8,000 registered hotspots. March 2020 shows the highest number across the years and months, with over 9,400.

The number of registered hotspots can influence the average brightness and FRP as presented above. The more hotspots there are, the lower the averages tend to be. This is particularly noticeable in the peak average FRP of 8.8 GW in May 2021, when comparatively few were registered from orbit (172).

March also tends to be the month in which the highest energy radiation (FRP) of over 100 GW is registered, which may be due to the large geographical area in which fires may burn simultaneously. For an idea on where the hotspots are registered, Figure 3 plots the coordinates for the year 2023.

A more interesting question arising from this analysis may be: What else is fuelling those hotspots at high FRP rates? 93% of these hotspots are below 10 GW, indicating similar types of potential fires in terms of scope and fuel; however, 2% showed double that FRP rate, at least 20 GW; and 0.3% exceeded rates of 50 GW, reaching over 100 GW and even 200 GW.<sup>9</sup> These hotspots are likely not just the burning of agricultural residues but may extend into burning adjacent forest areas or potentially other materials. Unfortunately, the

available data does not provide further insight into the type of material being burned.

### Conclusion

Placing the data on fire hotspots and pollution levels side by side displays their simultaneous occurrence and temporal relationship. The incidences from within Thailand's borders and the surrounding provinces of Chiang Mai city indicate a relationship with the seasonal haze – which should be unquestionable by now. These hotspots are predominant in March each year, although the initial pollution effects can be felt as early as December of the previous year and last into May of the subsequent year. The relative consistency among the brightness may indicate that similar materials are being combusted, and the majority of hotspots radiating at below 10 GW may further support this assumption. However, a small percentage of hotspots reach higher rates of radiated energy, potentially indicating that other materials besides agricultural residues are being burned regularly.

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<sup>9</sup> Number of fires equal or below 10 GW: 114,518; number of fires above 10 GW: 8,706; number of fires above 20 GW: 2,392; number of fires above 50 GW: 385.