RecyGlo

# PM2.5 POLLUTION AND WASTE MANAGEMENT IN NORTHERN THAILAND:

## Causes, Impacts, and Strategic Solutions

Prepared by
**RecyGlo Thailand 2024**

**RECYGLO**’s mission is to process materials in a safe, non-hazardous manner with an aim to keep the world environmentally clean; promote sustainable development and implement circular economy in order to create a more resilient future for all, and; help businesses and individuals minimize their environmental impact through effective solutions.

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# EXECUTIVE SUMMARY

Thailand has been struggling with increased air pollution and haze problems that have severely affected its population far and wide. Small particulate matter, commonly referred to as **PM2.5**, is a by-product of waste combustion is of special concern since the particles are invisible to the naked eye, yet are able to cause a multitude of problems – which include, but are not limited to health, environmental, and socio-economic issues.

Out of the 4 distinct regions in Thailand, **Northern Thailand** has been the most affected and is the main focus in this review since the region has experienced a huge impact to its environment through heavy deforestation and open burning with regards to contract farming schemes. The region is well-known for its distinct culture and cool atmosphere, especially during November to January, that draws plenty of local and international tourists to visit and explore.

However, times have changed – Chiang Mai province, located in Northern Thailand, is now notorious for its high PM2.5 pollution, and has been labeled "**world's most polluted city**" as reported by domestic and international news sources.

This review will explore the **causes** and **impacts** of increased air pollution in Northern Thailand, as well as **government efforts** and **strategies** to address and mitigate the PM2.5 situation on the local and international scale. Through this review, **RecyGlo Thailand** aims to **raise awareness** of the PM2.5 situation in Thailand and surrounding countries within the **Greater Mekong Subregion (GMS)** and **ASEAN** for our readers. This review also **engages with local communities** through *online surveys* and *interviews* to ensure their concerns are being heard.

Let us play our part and take individual steps to be more conscious of our organic waste management and how it impacts the environment and our health in these *hazy* times.

Image credit | Lauren DeCicca/Getty Images

# Acknowledgement & Authors

## Acknowledgement

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# INTRODUCTION

## Overview of PM2.5

**Particulate matter (PM)** or particle pollution refers to a mix of solid particles and liquid droplets suspended in the air. This includes visible particles (i.e. dust and soot) and microscopic particles that can only be detected by an electron microscope. In general, this pollution is categorized into **PM10** (diameters of 10 micrometers or smaller) or **PM2.5**, which includes finer particles of 2.5 micrometers or less – approximately **30 times smaller than a human hair.** These particles may originate from construction sites and fires, or may form in the atmosphere through reactions that involve pollutants (i.e. sulfur dioxide and nitrogen oxides) from power plants, industries, and vehicles.

Due to the minute size of PM2.5, these particles **can penetrate deep into the lungs and enter the bloodstream** (US Environmental Protection Agency, 2024). This penetration can lead to various **health problems** that range from respiratory issues like asthma and bronchitis to more severe conditions such as cardiovascular diseases and lung cancer. Additionally, PM2.5 can remain suspended in the air for extended periods, which **increases the risk of inhalation** and subsequent health impacts (Xing et al., 2016).

The composition of PM2.5 depends on the source. Common sources include agricultural regions that practice the **"slash-and-burn"** of organic matter in order to **clear the farmland for the next planting season**, especially from January to April (Punsompong et al., 2021; Jainontee et al., 2023).

The chemical composition of PM2.5 is critical – particles with higher concentrations of heavy metals or organic carbon compounds may pose more severe health risks in comparison to soil or salt compositions (Zhang et al., 2018).

In **Chiang Mai**, a province located in Northern Thailand (Fig. 1), PM2.5 pollution is a significant **public health concern** that occurs every year especially during the dry season.

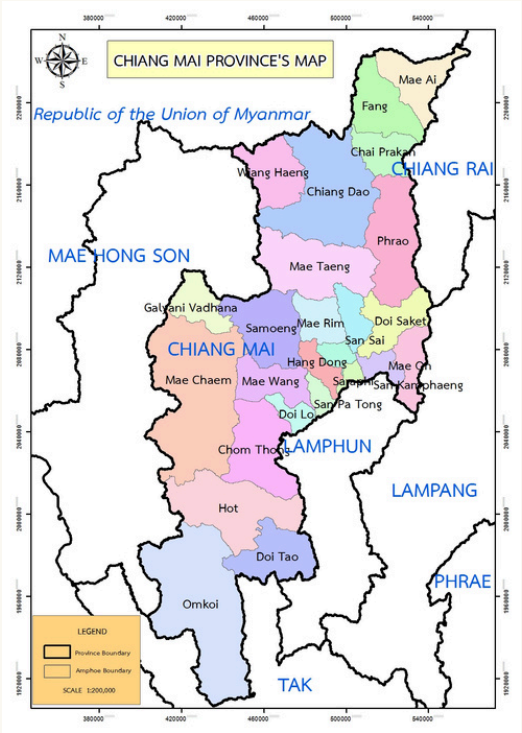



**Fig. 1.** Map of Chiang Mai province.
(Source: Chiang Mai Governor Office)

# Challenges with organic waste management

The management of organic waste from the agricultural sector presents several challenges. In Thailand, large amounts of biomass waste is generated and often leads to various **environmental and management issues.** While some rural communities have successfully adopted biomass utilization technologies to **convert waste into useful products (i.e. biogas and organic fertilizers)**, many others struggle with stench and disposal problems associated with the decomposition of organic matter (Tantiwatthanaphanich & Zou, 2016).

A major challenge is the **lack of proper waste management** in many rural areas. Without adequate facilities and expertise, organic waste ends up generating more pollution and health problems rather than being effectively transformed into renewable energy or other beneficial products. For instance, biomass decomposition can produce **unpleasant odors and greenhouse gasses** that further exacerbate air quality issues, particularly in regions like Northern Thailand where agricultural burning is common (Department of Alternative Energy Development and Efficiency, 2015).

Additionally, there are **financial and technical barriers** that prevent the implementation of biomass utilization projects on a larger scale. Many small-scale farmers and rural communities lack the initial capital and technical know-how needed to set up and maintain effective biomass conversion systems.

Although **government policies and incentives** aim to support these initiatives, the practical difficulties to manage and scale up these technologies remain as significant hurdles (Papong et al., 2004). Addressing these challenges requires coordinated efforts between local communities, government agencies, and research institutions to develop and implement sustainable waste management solutions.



Image credits | Food waste: Justin Sullivan/Getty Images,
Soil compost: Brent Lewin/Getty Images

# Seasons and regions affected by PM2.5

PM2.5 pollution in Northern Thailand is particularly severe during the **dry season (November to April)** where the concentration of fine particulate matter **frequently exceeds safe levels** due to the widespread burning of agricultural waste and forest fires. These activities release significant quantities of PM2.5-bound polycyclic aromatic hydrocarbons and other toxic pollutants into the atmosphere (Junpen et al., 2018).

According to Amnuaylojaroen et al. (2023), the dry season in Northern Thailand not only sees increased PM2.5 concentrations due to local agricultural burning, but also suffers from the **transboundary haze pollution** from neighboring countries like Myanmar, Laos, and Cambodia. PM2.5 levels in Lampang, Chiang Rai, and Chiang Mai can reach between 150-195 $\mu g/m^3$ from January to May.

High temperatures, favorable wind, and relative humidity contribute to elevated PM2.5 concentrations in Northern Thailand. Massive amounts of smoke from fire-related activities in Thailand and neighboring nations contribute to the **limited visibility** in Northern Thailand, particularly at elevations of 1 km above ground. In April, visibility reductions range from 70-90% throughout all provinces (Amnuaylojaroen et al., 2023).

Image credits | Haze over Bangkok: Thairath,
Masked individuals: Pongmanat Tasiri/SOPA Images

# CAUSES OF PM2.5 IN NORTHERN THAILAND

## Open burning of organic waste

Every year from January to March, Northern Thailand faces serious smog problems which reflect an increase in PM2.5 severity and environmental issues (Khunthong et al., 2023). One major cause is attributed to the open burning of organic waste, which includes agricultural waste, sugarcane, and rice straw biomass that was previously planted and harvested, in order to clear the farmland and prepare the soil for the next crop cycle (Pongpiachan et al., 2017). This process is known as the **"slash-and-burn" method** that is common in Southeast Asia (Punsompong et al., 2021).

Although the **open burning of agricultural waste has been prohibited** through the **Eight-Point Plan** since 2013 to restrict open burning during an "80-day period" (from January to April) with extensive awareness campaigns and close examination of the haze situation, **corn residues are the highest burned organic by-product** with the least utilization by farmers in comparison to other economic crops in Northern Thailand (Lualon et al., 2013; Thola et al., 2022).

In a documentary interview conducted by Marchitelli (2016) with Dr. Michael Shafer, Ph.D. about the burning season in Northern Thailand, Shafer mentioned, "The (primary crop) for Northern Thailand...has always been **rice**. Rice straw is (the) dirtiest agricultural waste to burn (as) it produces...a tremendous amount of particulate matter, ...smog precursors, and gasses that (are bad) for the atmosphere. (Over the) last few years, **corn** has been added to the agricultural mix. (There has been a rise in) **contract corn growing** – and the growing of corn (2-4) seasons (annually means that a lot of) new corn stalk...is burnt...thus increasing the amount of particulate matter."



Image credit | Hilal Abdullah/Getty Images

## Forest fires

Forests are not only significant to sustain life and biodiversity, but play an essential role in Thailand's economic and agricultural sectors as well. In 2019, Forests were reported to make up **31.68% of the total land area** in Thailand, however, this number has been on a gradual decline due to fires caused by human activities (Prapatigul & Sreshthaputra, 2022). Forest fires are a source of air pollution and haze that seriously affects many people and all sectors of the economy. Fire-related activities normally begin in February and last until early April, and have been a normal occurrence in Chiang Mai according to data since 2012 (Global Forest Watch, n.d.).

**Forest fires are the main product of human activities** during the dry season – namely land clearing, scavenging, hunting, pest removal, and "slash-and-burn" farming preparation (Yasmi et al., 2017; Khunthong et al., 2024). However, forest fires in Northern Thailand are increasingly difficult to manage due to the effects of **global climate change** that Thailand is vulnerable to which includes heat, drought, and flooding that heavily impacts agriculture and food security (Khunthong et al., 2024; United Nations Development Programme, 2024).

Furthermore, the outbreak of sudden forest fires are a **contributor to increased air pollution** in Northern Thailand. Fire-related activities are the main cause of PM2.5 pollution (Amnuaylojaroen et al., 2023). In 2020, a **major bushfire in Doi Suthep-Pui National Park** (Fig. 2) caused extensive damages and heightened the PM2.5 levels to 1,000 μg/m$^3$, which was 20 times greater than safe levels for human exposure (Tanraksa & Bangprapa, 2020). This is a **recurring problem** as wild forest fires in national parks in and around Chiang Mai recently occurred in 2024 and persisted for 2 weeks. Moreover, local governments faced problems of limited funding and lack of rain to manage and prevent the recent fires. In addition, it is important to note that wind carries the fine dust and smoke produced from these forest fires to populated areas, and creates adverse health and environmental effects (Tanraksa & Bangprapa, 2024).

**Fig. 2.** Doi Suthep-Pui National Park forest fire in 2020.
(Source: Bangkok Post)

# Increased corn farming

Corn or maize farming has risen sharply over time to meet the demand for human food and animal feed. In Chiang Mai, **Mae Chaem** is the main site for corn farming and accounts for **70% of corn production** in the province (Thola et al., 2022). However, most of the terrain (more than 60-70%) in Mae Chaem is steep and leads to water shortages for agricultural use during the dry season, which is one of the causes for encroachment into protected forest areas for illegal farming, and a source of conflict between locals and the government. Due to these difficulties that local farmers have encountered, thus, a crop that requires less water, can produce high yield and generate profits, and does not need high maintenance is preferred – namely, **maize** (Prapatigul & Sreshthaputra, 2022).

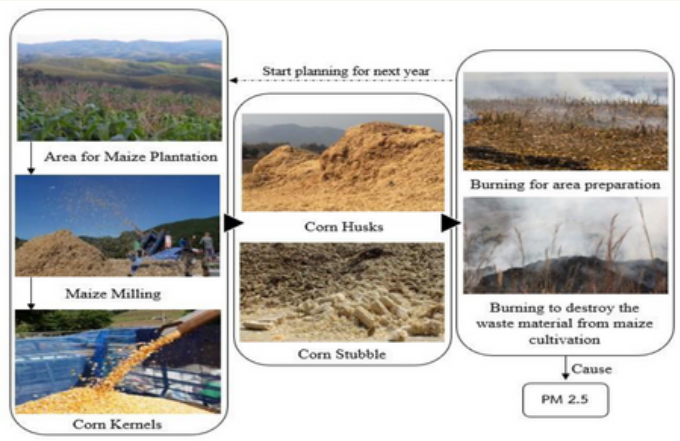



**Fig. 3.** Cycle of corn production in Mae Chaem. (Source: Prapatigul & Sreshthaputra)

From 2005 to 2020, corn production in Mae Chaem has increased tremendously from 22,000 to 87,630 tons, whereas the total area for corn plantations expanded from 7,770 to 20,619 hectares (ha). However, this has led to the **generation of more than 10 million tons of corn waste** or corn residue, which is a significant source of organic waste for open burning and contributes to the generation of PM2.5 in Northern Thailand. During the burning season in Chiang Mai, 90% of air emissions stems from the burning of corn residues (Thola et al., 2022).



Image credits | Corn field: Thampapon Otavorn/Getty Images, Slash-and-burn farming: oneclearvision/Getty Images

The **Charoen Pokphand Group (CP Group)** is one of the largest agricultural producers and companies in Thailand. More importantly, the CP Group is the main driver behind the rise of contract maize farming in Southeast Asia, particularly in the **Greater Mekong Subregion (GMS)** (Fongissara & Buddharaksa, 2022). In 2003, Thailand proposed and signed a strategic partnership with Cambodia, Laos, and Myanmar to lessen the socio-economic gap in the GMS and to encourage prosperity and solidarity in these ASEAN countries, otherwise known as the **Ayeyawady-Chao Phraya-Mekong Economic Cooperation Strategy (ACMECS)**. In total, there are 5 member countries under this partnership with Vietnam that joined later in 2004 (Department of Foreign Trade, n.d.). The CP Group has benefited the most from the ACMECS partnership through **contract maize farming** operations (Fongissara & Buddharaksa, 2022).

For farmers, contract farming can help to alleviate symptoms of poverty within a short time. Farmers are able to make **decent profits** within a few years, and this has led to the **rise of popularity** of contract farming that many villagers have adopted to sustain their livelihoods. However, due to rapid population and socio-economic growth, increasing costs of labor in Thailand, and rising demands for food, the CP Group has sought for lower production costs and new consumer markets in the GMS region (Woods, 2015). Notably, Thailand has played a role in the development of contract maize farming operations in the **Shan State** (Myanmar) in order to **supply over 75%** of its maize harvests to **China** to serve as **animal feed**. China currently stands as one of the largest animal feed industries globally (Woods, 2015).

In the 2000s, Thailand and Myanmar signed an agreement to allocate about 700,000 ha of land for contract maize farming as a **replacement for opium cultivation** under CP Group operations. However, due to political tensions in the Shan State, proper implementation of contract maize farming operations was delayed and prompted the establishment of several livestock feed industries along the Thai-Myanmar border in order to supply the Thai demand for meat. Aside from the open burning of maize residues and the subsequent generation and impacts of PM2.5, additional problems such as **debt and asset loss** among farmers who cannot afford contract farming schemes have been created as well (Jepsen et al., 2019; Woods, 2015). In 2023, the CP Group denied its support in maize contract farming and "slash-and-burn" practices in Northern Thailand. Additionally, the CP Group allegedly claimed that all corn seeds used in its farms were produced legally and the conglomerate did not support farmers who practiced the open burning of agricultural waste (Bangkok Post, 2023).

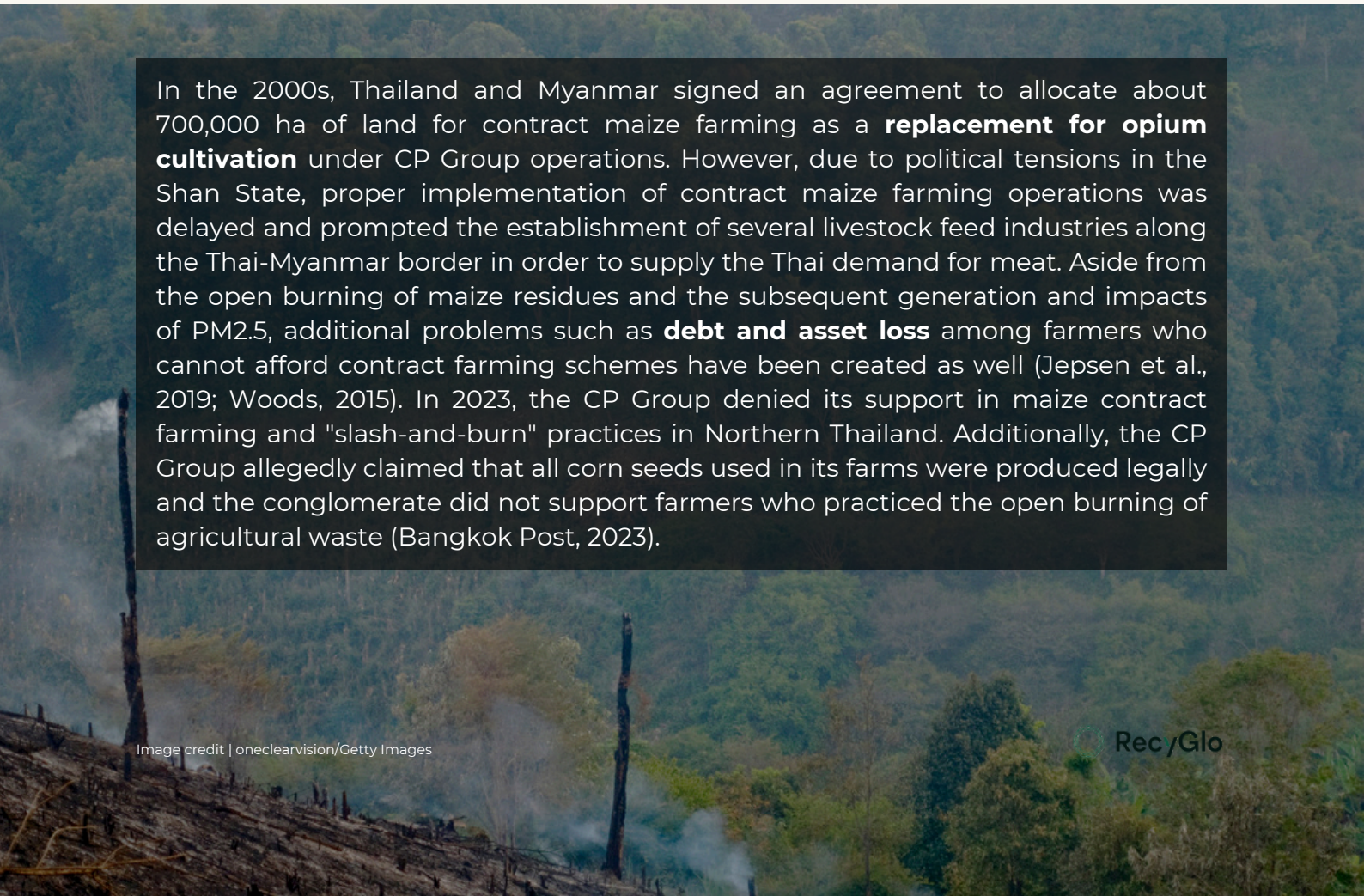


Image credit | oneclearvision/Getty Images

## Lack of forests and tree cover areas

Between 2001 and 2023, Chiang Mai has lost 124 kilohectares (kha) of tree cover (7.7% loss) that amounts to **68.2 million tonnes** of carbon dioxide emissions (Global Forest Watch, n.d.).

From 1995 to 2005, the total area of tree covers in Chiang Mai has been depleted due to **deforestation for agricultural and urban development**, which increased by 3.46 and 185.19% respectively (Fig. 4). Additionally, 2.55% or 19,845 ha of forest cover and 20.08% (1,044 ha) of water bodies were lost to agriculture in both protected and non-protected areas. Although protected forest areas have been established and are effective in the conservation of forests in protected zones, **deforestation in general has not de-escalated** (Lee et al., 2022).

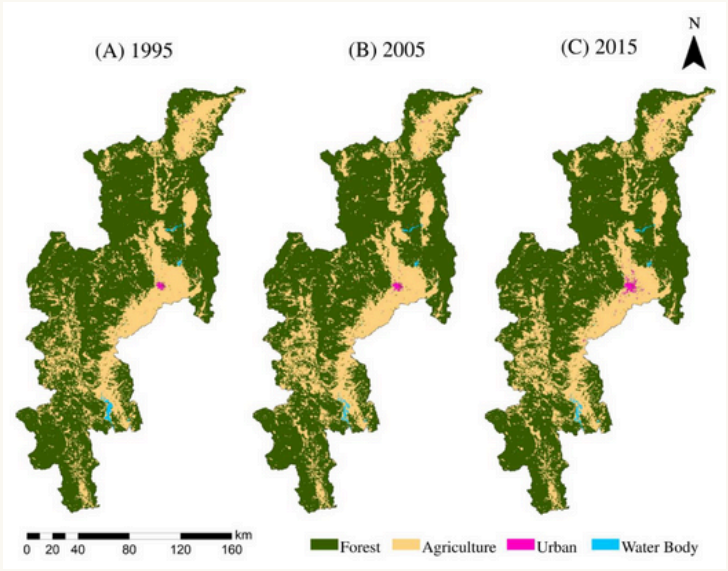


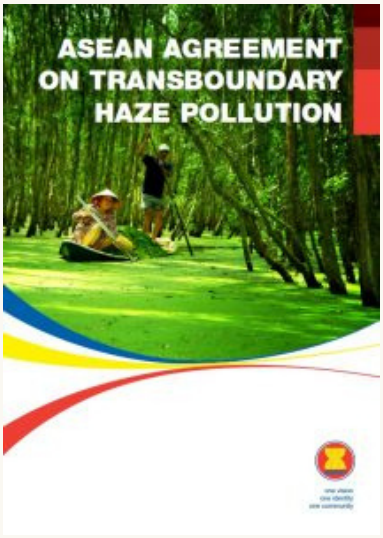

**Fig. 4.** Land cover maps in Chiang Mai in 1995, 2005, and 2015. (Source: Lee et al.)

Additionally, **unsustainable and illegal logging** are rampant in the GMS. Agricultural expansion, infrastructure development, illegal logging, mining, and forest fires are activities that negatively impact forest changes in the GMS region. From 1990 to 2015, Cambodia and Myanmar recorded a huge decrease in forest cover area at 27% (12.94 to 9.46 million ha) and 26% (39.22 to 29.04 million ha) respectively. Meanwhile, Laos, Thailand, and Vietnam have experienced a rising trend in forest cover area due to reforestation efforts and the establishment of government laws to mitigate deforestation (Yasmi et al., 2017).



Image credit | Rich Carey/Getty Images

# Transboundary haze pollution




However, the PM2.5 situation in Northern Thailand is not solely caused by activities that contribute to pollution in the immediate vicinity but also comes from activities in neighboring countries, such as Myanmar and Laos (Sipinski, 2023). This phenomenon is known as the **transboundary haze pollution**. Issues in the GMS are tied to the expansion of **corn farming for the livestock industry**, which leads to hotspot problems in 30% of corn-growing areas across 3 regions and countries: Northern Thailand, the Shan State in Myanmar, and Northern Laos (Fongissara & Buddharaksa, 2022).

These challenges are part of the larger transboundary haze problem, which cannot be fixed by the reduction of open burning in a single country. Hence, Fongissara & Buddharaksa (2022) suggested that the Association of Southeast Asian Nations (ASEAN) members are required to take more serious steps to effectively address these issues.

Despite efforts to address the issue, PM2.5 levels in Northern Thailand have continued to rise and set new records for unhealthy air quality in recent years. Marks (2021) pointed out that both ASEAN and the Thai government have struggled to curb transboundary pollution from biomass burning in neighboring countries.

Image credits | Forest fire: gece33/Getty Images,
Bangkok: ChanwitOhm/Getty Images

While cooperation with these countries is a positive step, Thai leaders have the power to control the actions of Thai companies that profit from the smoke that originates from these regions. The **increase in hotspots is associated with a regional boom in maize production for the animal feed industry**, driven by **rising meat consumption**, especially in China. Companies like the **CP Group** have played a significant role in this expansion, with CP Group's contract farming in Myanmar's Shan State that supplies China's chicken-feed market and contribution to the rise in maize production in Laos (Marks, 2021).

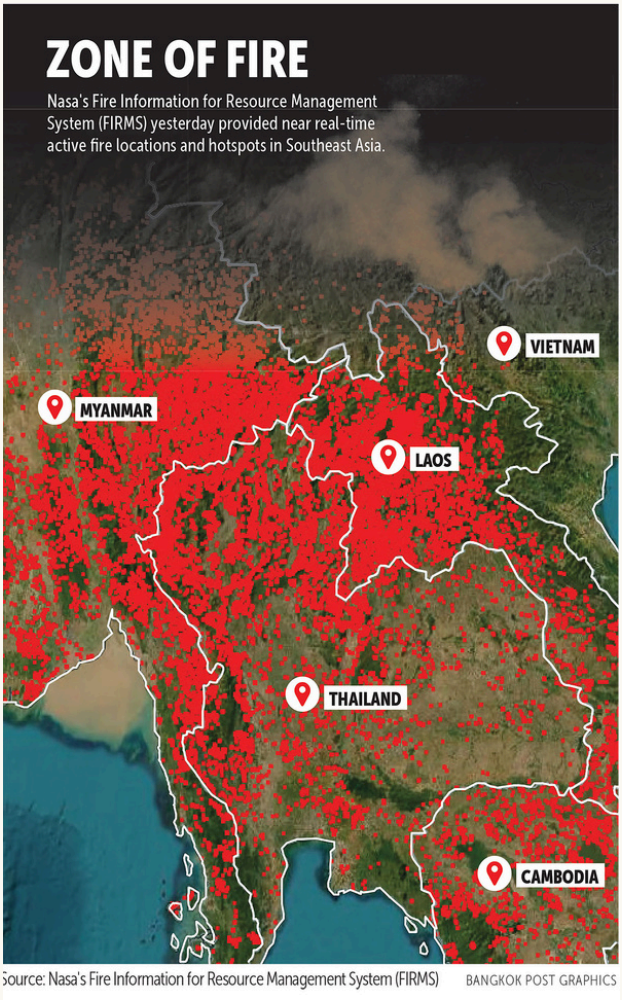



**Fig. 5.** Active hotspots in Southeast Asia.
(Source: Bangkok Post)

Other major Thai companies, such as **Mitr Phol** and **Khon Kaen Sugar Industry**, have also expanded into neighboring countries like Cambodia and Laos, where burning from large-scale sugarcane plantations further contributes to PM2.5 emissions (Marks, 2021). Therefore, it is unfair for Thailand to point fingers at neighboring countries and blame transboundary haze when a significant part of the problem originates within the country and is driven by its own businesses.

Image credit | Burning farmland: Thailand Environment Institute, Sugarcane farm: LifeOnWhite

# DATA COLLECTION

## Environmental baseline

Thailand is divided into 4 regions: Northeastern, Northern, Central, and Southern. The study by Jainontee et al. (2023) focused on 3 regions in **Northern Thailand**, namely Chiang Mai, Chiang Rai, and Mae Sai (part of Chiang Rai province).

Northern Thailand is a **key region to address various regional sustainable development challenges** and is located within the **Ping River Basin** that plays a significant influence on the nation's agricultural activities. The Ping River, a major tributary of the Chao Phraya River, is essential to the country's economic vitality (Masud et al., 2016). According to Jainontee et al. (2023), **Chiang Rai** was selected and examined since the province **experiences good air quality** for most of the year (about 9-10 months), yet it is **susceptible to air pollution** during the burning season; meanwhile, **Chiang Mai** is one of the largest provinces in Thailand with a high population density and **large focus on tourism**, and **experiences heavy air pollution**, as previously discussed in this report. Lastly, **Mae Sai district** was included as well since it is a **border region and economic zone between Myanmar and Thailand** that is **prone to air pollution and emissions** generated from transportation, commerce, and waste.

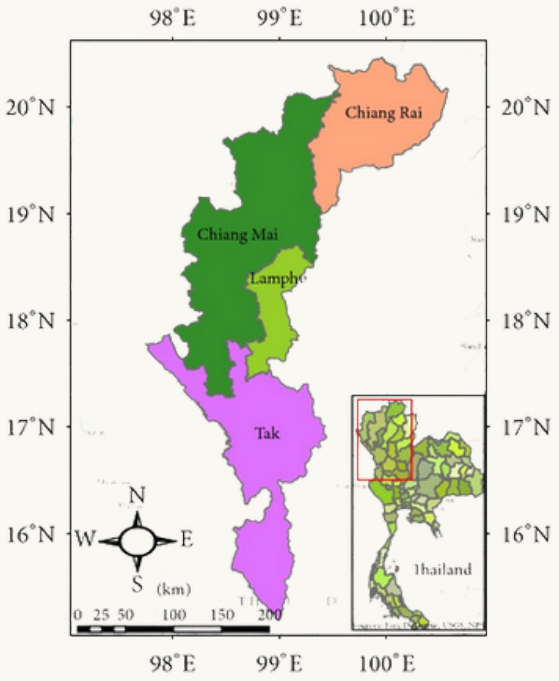



**Fig. 6.** Partial map of Northern Thailand. (Source: Masud et al.)

*Ping River, Chiang Mai*

*Chao Phraya River, Bangkok*

Image credits | Ping River: dreamedmstudio/Getty Images, Chao Phraya River: Chaded Panichsri

## Historical weather patterns and seasonal variations

Northern Thailand experiences distinct seasonal variations due to its tropical monsoon climate, characterized by **3 main seasons**: the **cool** season (November to January), the **hot** season (February to May), and the **rainy** season (June to October). Historically, the region's weather patterns have been influenced by the **monsoon winds** – the **southwest monsoon brings heavy rainfall** during the rainy season, and the **northeast monsoon contributes to cooler and drier conditions** during the cool season. In December and January, the arrival of cold air masses from China causes nighttime temperatures to drop significantly in northern cities like Chiang Mai, Lampang, and Udon Thani, and often reaches around 5°C (41°F) or lower. However, by February, daytime temperatures begin to rise and reach 34-35°C; by March to May, temperatures can soar to 36-38°C, with peaks that exceed 40°C (Climates to Travel, n.d.).

The monsoon season in Northern Thailand typically extends from mid-May to mid-October and annual precipitation ranges from 1,000-1,500 mm. Rainfall is minimal and infrequent from mid-November to April, while the monsoon period brings substantial precipitation, particularly in early May and later in August and September, which are the peak months for rainfall.

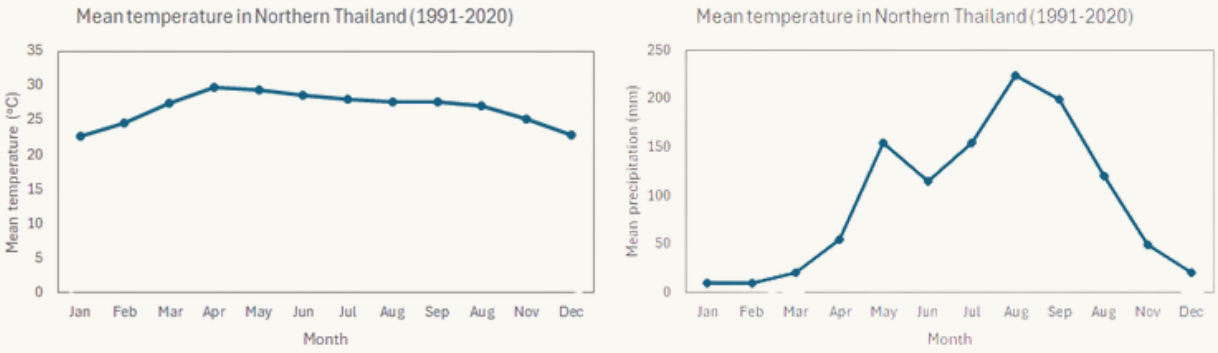



**Fig. 7.** Average temperature (left) and precipitation (right) in Northern Thailand. (Adapted from Climates to Travel)


Image credit | shylendrahoode/Getty Images

## Historical PM2.5 quality

Northern Thailand consistently faces air pollution challenges during the **dry season**, which spans from **January to mid-April**. **PM2.5 concentrations notably increase during this period**, as levels begin to rise around mid-January, then peak in March, and gradually decline (Suriyawong et al., 2023).

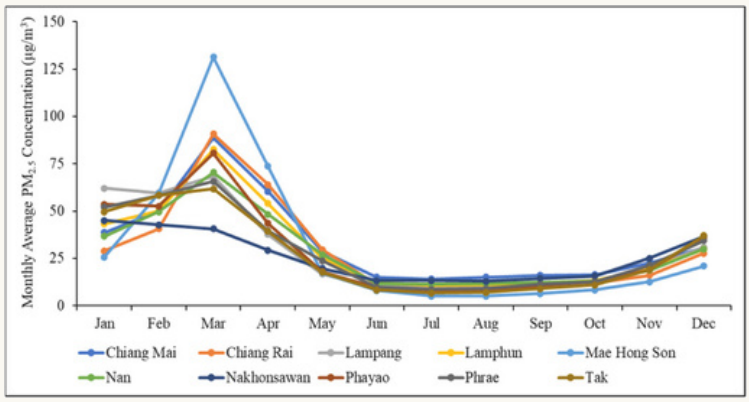



**Fig. 8.** Concentration of PM2.5 by month.
(Source: Suriyawong et al.)

**PM2.5** is a significant air pollutant known for its **harmful effects on human health**. It can enter the body through the respiratory system, which leads to adverse pulmonary and cardiovascular outcomes, as well as the negative effects on birth. In many countries, the primary sources of PM2.5 are **combustion activities** such as industrial processes and vehicle emissions. However, the elevated **PM2.5 concentrations observed in Northern Thailand** during the dry season **differ from those typically found in other regions**. The sources of this pollution primarily include **open fires**, such as forest fires and the burning of crop residues or organic waste, which typically subside by mid-April. The release of fine particulate matter or PM2.5 during the dry season from the open burning of biomass has had a prolonged detrimental effect on the health of residents in Northern Thailand (Jainontee et al., 2023).

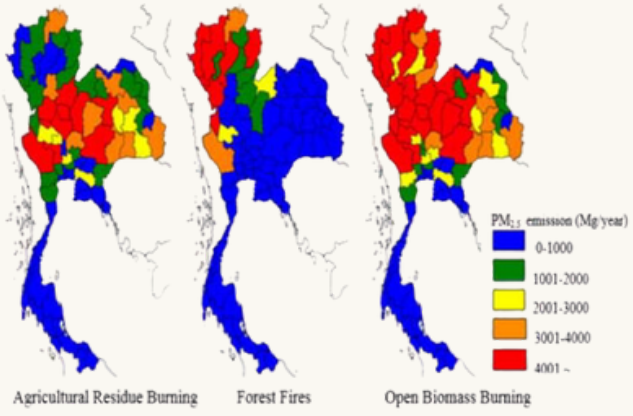



**Fig. 9.** PM2.5 distribution from biomass burning in Thailand.
(Source: Phairuang et al.)

Air quality data was sourced from the Pollution Control Department (PCD) for the period 2019-2021. Data from **3 air quality monitoring stations** based in **Chiang Mai, Chiang Rai, and Mae Sai** were analyzed to characterize the PM2.5 levels in these areas and to identify periods of pollution episodes. The air quality index (AQI) used by the PCD, under the Ministry of Natural Resources and Environment in Thailand, is based on the AQI system developed by the U.S. Environmental Protection Agency.

**Table 1.** Concentration of air pollutants equivalent to the AQI value in Thailand.

| AQI | | $PM_{2.5}$ ($\mu g\ m^{-3}$) 24-hour average | $PM_{10}$ ($\mu g\ m^{-3}$) 24-hour average | $O_3$ (ppb) 8-hour average | CO (ppm) 8-hour average | $NO_2$ (ppb) 1-hour average | $SO_2$ (ppb) 1-hour average |
|---|---|---|---|---|---|---|---|
| Level 0: Excellence | 0–25 | 0–25 | 0–50 | 0–35 | 0–4.4 | 0–60 | 0–100 |
| Level 1: Satisfactory | 26–50 | 26–37 | 51–80 | 36–50 | 4.5–6.4 | 61–106 | 101–200 |
| Level 2: Moderate | 51–100 | 38–50 | 81–120 | 51–70 | 6.5–9.0 | 107–170 | 201–300 |
| Level 3: Unhealthy | 101–200 | 51–90 | 121–180 | 71–120 | 9.1–30.0 | 171–340 | 301–400 |
| Level 4: Very unhealthy | > 200 | ≥ 91 | ≥ 181 | ≥ 121 | ≥ 30.1 | ≥ 341 | ≥ 401 |

**Table 2.** Frequency of different $PM_{2.5}$ AQI Level of the selected stations in 2019–2021.

| Year | The period with unhealthy AQI | | | Frequency of AQI in "selected range" | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Start date | End date | Day range | Very unhealthy | Unhealthy | Moderate | Satisfactory | Excellent | ND |
| | | | | 35T-Chaing-Mai station | | | | | |
| 2019 | March-11 | April-13 | 34 | 26 | 8 | 0 | 0 | 0 | 0 |
| 2020 | February-28 | April-12 | 45 | 23 | 16 | 3 | 0 | 0 | 3 |
| 2021 | March-3 | April-3 | 32 | 10 | 20 | 2 | 0 | 0 | 0 |
| | | | | 57T-Chiang-Rai station | | | | | |
| 2019 | March-14 | May-3 | 51 | 23 | 24 | 4 | 0 | 0 | 0 |
| 2020 | February-17 | April-9 | 53 | 28 | 21 | 4 | 0 | 0 | 0 |
| 2021 | March-8 | April-4 | 28 | 8 | 17 | 2 | 1 | 0 | 0 |
| | | | | 73T-Mai-Sai station | | | | | |
| 2019 | March-11 | May-3 | 54 | 42 | 8 | 0 | 2 | 0 | 2 |
| 2020 | February-16 | April-10 | 55 | 39 | 14 | 1 | 0 | 0 | 1 |
| 2021 | March-1 | April-24 | 55 | 35 | 8 | 6 | 4 | 2 | 0 |

**Fig. 10.** Occurrence of PM2.5 AQI levels at various selected stations.
(Source: Jainontee et al.)

Northern Thailand experiences **significant air quality deterioration during the dry season**, particularly in Chiang Mai, Chiang Rai, and Mae Sai. From 2019-2021, the **"Very Unhealthy"** AQI level (red color) was the most frequent, especially in **Mae Sai** (Fig. 10), where up to 42 days was recorded in 2019. The data shows that **poor air quality persists for extended periods**, typically from February to April, with the worst conditions in March (Jainontee et al., 2023). According to Sresawasd et al. (2021), PM concentration can be reduced sometimes due to high wind speeds and precipitation.

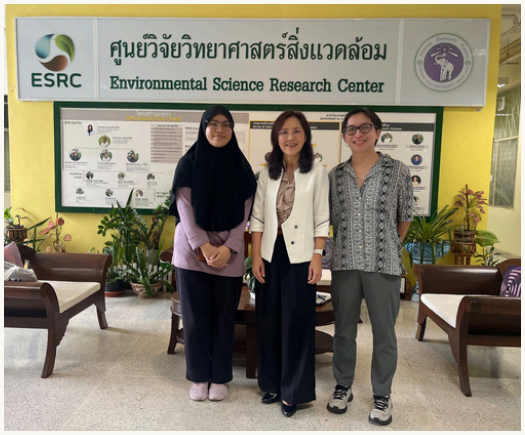
**Fig. 11.** Haze in the Mae Sai border region.
(Source: Siamrath)

## Voices of the Experts

This review has also engaged with **several experts from Chiang Mai University, Northern Thailand**, to further confirm and solidify our findings. Some of the conversations are quoted below:

“The main challenge is open burning, especially during the dry season. Forest areas are burning, and despite efforts, we cannot fully solve this. The **zero-burning policy was successful at first, but unfortunately, people still burn**.”

"The zero-burning policy had potential, but after two years, people went back to burning. The local government is responsible for enforcing it. **They *(local authority)* have an agreement with the public, allowing burning if registered in the system.** The process includes monitoring air quality three to five days in advance, and if conditions allow, the burn is permitted. Despite these efforts, the zero-burning policy doesn’t work as intended.




*Dr Somporn with RecyGlo Researchers: Syukriah and Jazreen*

"Transboundary air pollution is a significant problem in Southeast Asia. The **Thai government has been leading solutions in the northern part**, employing more modern technology and installing monitoring stations with local sensors. **Campaigns have been launched in neighboring countries like Laos and Vietnam**, where we’ve also **shared technology from the United States** to help monitor air quality. However, at the government level, the initiatives are not as successful. It's better to work at the local level where people can share information and start smaller-scale solutions."

"**As an academic**, ***I believe the problem of PM 2.5 pollution will persist for the next 10 to 20 years.*** It’s not an easy problem to solve. Even though more stakeholders are becoming involved, we still **need more budget, more personnel, and deeper involvement with local communities**. We need authorized individuals at both the country and provincial levels to drive change."

**Remarks from Assoc. Prof. Dr. Somporn Chantara,**
**Head of Envrionmental Science Research Centre**

# Voices of the Experts

**Remarks from Dr Matthew Robson,**
**Faculty of Political Science and Public Administration**

"There are *conflicting reports in the media*. Some say the haze is coming from surrounding countries, carried by the wind into Thailand, but **much of it actually originates from rural areas in Northern Thailand.** The primary source is agricultural practices—after harvest, farmers burn crops to prepare for the next season, which generates a lot of smoke. This smoke gets funneled into populated areas, worsening the air quality."

"**From a policy perspective, we need to offer local farmers some form of compensation or incentive to adopt sustainable practices.** At the same time, we should be **improving regulations for businesses involved in contributing to the pollution**."


*CMU Researchers share ideas on DIY Air Purifiers*

"*I don't believe punishing people is the answer.* **If large conglomerates are involved, there need to be better regulations and frameworks in place to ensure they follow best practices.** Farmers should be provided with **more technology** and **financial support**. The *rural population* is severely impacted by these practices. **They *(rural population)* are not really interested in SDGs or UN policies—they just need practical solutions**."

"The pollution definitely affected my health. I experienced a *throat infection, and the hospital told me it was likely related to the haze*. I was on antibiotics for two weeks. I have also noticed that **students wear masks in the classroom, and air purifiers are now common in the University classrooms.**"

"**Community engagement is important in reducing PM2.5**. Grassroots initiatives play a key role in getting **local people involved.** These efforts can support the government's strategies by involving the people most affected by the pollution to ensure that **policies are both effective and sustainable in the long term**."

# Survey

In August 2024, an **online survey** was issued to the general public to gather the perception of the PM2.5 situation and waste management in Northern Thailand. The survey consisted of **10 questions** in total and collected **33 responses**. Table 1 shows the average results of questions that could be answered on a scale of 1 to 10, whereas the pie charts showcase the results of each multiple-choice question.

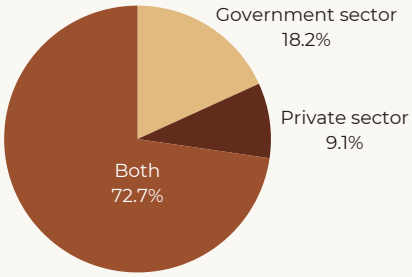
**Table 1.** Average results of qualitative survey questions.

| **Question** | How often do you hear news related to PM2.5? | How do you feel about the PM2.5 situation in Northern Thailand? | How much are your daily activities affected by the PM2.5 situation? |
|---|---|---|---|
| | (1=Never, 10=Very often) | (1=Very bad, 10=Very good) | (1=Not affected, 10=Very affected) |
| **Average answer** | **6.4** | **3.1** | **5.7** |

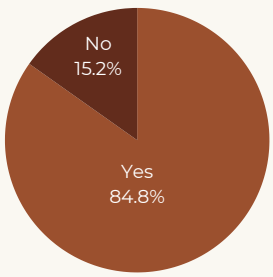
The results show that **most survey participants feel poorly about PM2.5**. Additionally, while many participants were aware of PM2.5-related news, there were also a portion of survey respondents who did not hear about PM2.5-related media or reports and were not impacted by the effects of air pollution.

24 participants (72.7%) thought that both the government and private sectors are accountable to manage the PM2.5 situation, and 19 respondents (57.6%) selected that initiatives which include the enforcement of stricter laws, sustainable waste management practices, as well as community engagement and awareness training should be applied in order to reduce PM2.5. 57.6% of survey participants think that the tourism, public health, and economic sectors are equally and severely impacted by the PM2.5 pollution. Lastly, 28 out of 33 respondents (84.8%) believe that individuals are responsible for the PM2.5 situation, while 72.7% of participants selected that the effective management of organic waste could help to minimize PM2.5 pollution.

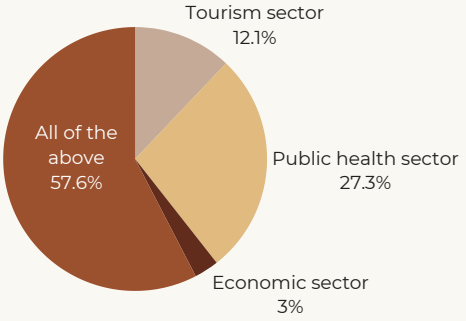
**Q. Is the government or private sector responsible for controlling the PM2.5 situation?**



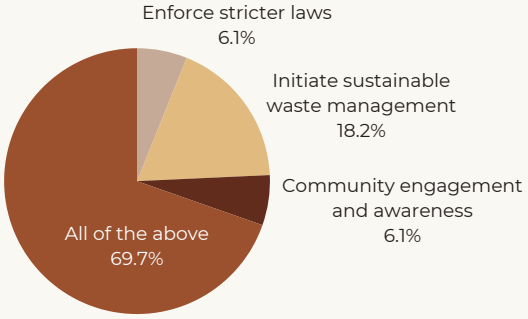

**Q. Do you think that individuals are responsible for the PM2.5 situation?**



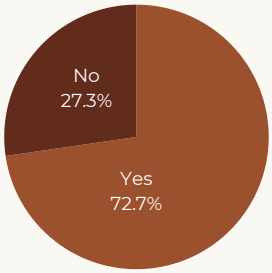
**Q. In your opinion, which sectors are severely affected by PM2.5?**




**Q. How do you think the PM2.5 situation can be reduced?**




**Q. By managing organic waste effectively, do you think we can resolve the PM 2.5 situation?**




Furthermore, survey participants were asked to provide additional **personal opinions and thoughts** of community involvement in waste management strategies. Several respondents believed that community engagement was crucial and there was a need to increase the awareness of waste management to reduce waste-related problems.

For example, respondents mentioned that the addition of **waste separation bins** and **waste sorting plants** could be implemented in local communities to raise engagement. Additionally, there should be **more education and training on waste management** to inform the public on the causes and consequences of waste problems, as well as the solutions and benefits to reduce waste generation. Community initiatives such as **clean-up days, recycling drives, and workshops** could foster a stronger sense of ownership among the local community to create a better understanding of the environment, so that people would be more motivated to clean and maintain it.

However, it should be noted that high-level initiatives which require participation and co-operation from multiple stakeholders is not an easy task to accomplish. Several survey respondents voiced out that **stricter law enforcement** from the government would be a step in the right direction, however, industries within the private sector that contribute to air pollution need to have **better control of their carbon emissions** too. Finally, the occurrence of **open burning and forest fires** caused by farmers and individuals must reduce in order to minimize the PM2.5 situation.



Image credits | Anemone123/pixabay

# IMPACT OF PM2.5 ON NORTHERN THAILAND

## Environmental impact

PM2.5 pollution in Northern Thailand leads to severe environmental impacts which include the **degradation of air quality, harm to ecosystems, and damage to forests**. Moreover, the pollution to climate change through its influence on atmospheric processes and reduced biodiversity disrupts natural habitats and weakens the resilience of the environment.

### i. Degradation of air quality

The degradation of air quality in Chiang Mai due to PM2.5 pollution is a significant environmental concern. Studies by Jainontee et al. (2023) revealed that a significant portion of PM2.5 in Northern Thailand stems from **open burning** that includes forest fires and the combustion of agricultural residues. Between January and May, images captured by NOAA/NASA Suomi NPP and NOAA 20 satellites showed numerous fires that occurred across Northern Thailand and is indicative of extensive burning attributed to **"slash-and-burn" practices** (Amnuaylojaroen et al., 2023).

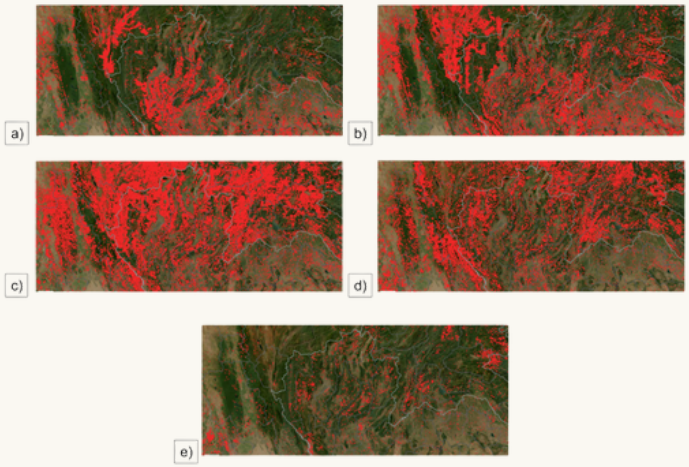



**Fig. 12.** Satellite images of fires in Northern Thailand during January to May 2020. (Source: Amnuaylojaroen et al.)

During the **dry season** (February to April), the air quality deteriorates drastically and often exceeds safe levels. Due to the lack of rainfall, there is **no natural mechanism to wash away the particles** and the **hot weather** leads to more frequent fires. Air pollution in this region is likely influenced by a combination of meteorological and geographic factors. Northern Thailand is **encircled by high mountains and subject to specific weather patterns** (i.e. calm winds and temperature inversions), which acts as a basin that traps pollutants and makes it the most affected area in Thailand during the dry season (Amnuaylojaroen & Kreasuwun, 2012).

Image credit | doidam10/Getty Images

Furthermore, Amnuaylojaroen et al. (2023) examined the spatial distribution of PM2.5 from January to May in 2020 and observed that most areas had moderate PM2.5 levels below 60 μg/m³ in January and February. In March, Lampang experienced slightly higher levels of PM2.5 and a sharp increase was observed in Chiang Rai and nearby provinces, with concentrations beyond 90 μg/m³. High levels continued in April, especially in Chiang Rai, but were evenly spread, and by May, PM2.5 levels had dropped significantly across the region, with most areas below 30 μg/m³.

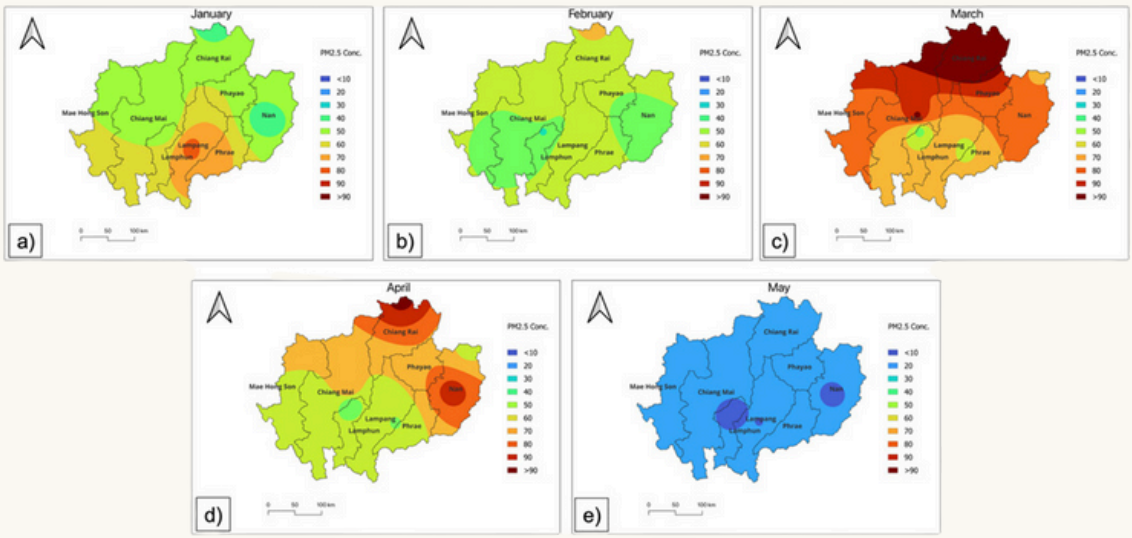



**Fig. 13.** Spatial distribution of monthly average PM 2.5 concentrations.
(Source: Amnuaylojaroen et al.)

According to the historical PM2.5 levels described in this report, it can be seen that the **pollution is worse during the dry season** from February to April every year. Additionally, PM2.5 particles are fine and can remain suspended in the air for long periods of time, and therefore reduces visibility significantly and creates haze. Fig. 14 shows that **April** has the highest effect on visibility due to PM2.5 in several provinces located in Northern Thailand (Amnuaylojaroen et al., 2023). This persistent pollution **reduces visibility, causes haze, and has a negative effect on the overall quality of life**. Furthermore, the degradation of air quality puts stress on local ecosystems, impacts plant and animal health, and contributes to the region's environmental decline.

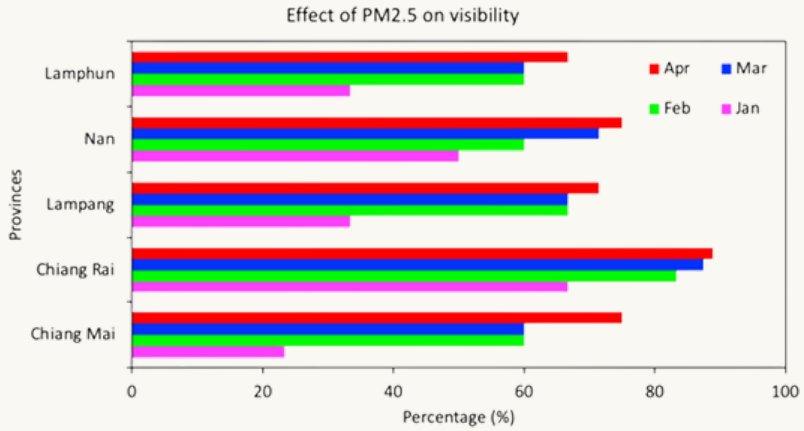



**Fig. 14.** Percentage of visibility due to PM2.5.
(Source: Amnuaylojaroen et al.)

## ii. Ecosystems and biodiversity

Most of Thailand's forests are located in the **northern region**; for instance, the Doi Suthep-Pui National Park is well-known for its rich biodiversity and has approximately 2,000 species of ferns and flowering plants, as well as 360 species of birds (Flaherty & Filipchuk, 1993; Thai National Parks, n.d.). However, PM poses a significant threat to **biodiversity** since its impacts are not limited to humans but extends to plants and animals as well.

**Elephants** show signs of distress (i.e. mood swings and tears) when exposed to haze. Since animals are unable to communicate with humans, the creatures have no choice but to tolerate and inhale the air pollution (Elephant Nature Park 2023). Since animals are unable to communicate with humans, the creatures have no choice but to tolerate and inhale the air pollution. A study revealed that **howler monkeys** exposed to PM2.5 from wildfire smoke experienced a **25% reduction in survival rates**, primarily due to respiratory complications and weakened immune systems which makes them more vulnerable to disease (AQI, 2022).

Moreover, researchers observed that PM2.5 pollution affects the behavior of Amazonian birds – one study noted a decrease in vocalization which could potentially impair the birds' communication and mating abilities (AQI, 2023). Gai et al. (2017) found that the impact of PM2.5 on mice fertility could highlight the adverse effects in both humans and animals, which include **increased risks of cardiovascular events**, lung cancer, chronic obstructive pulmonary disease and reproductive toxicity.

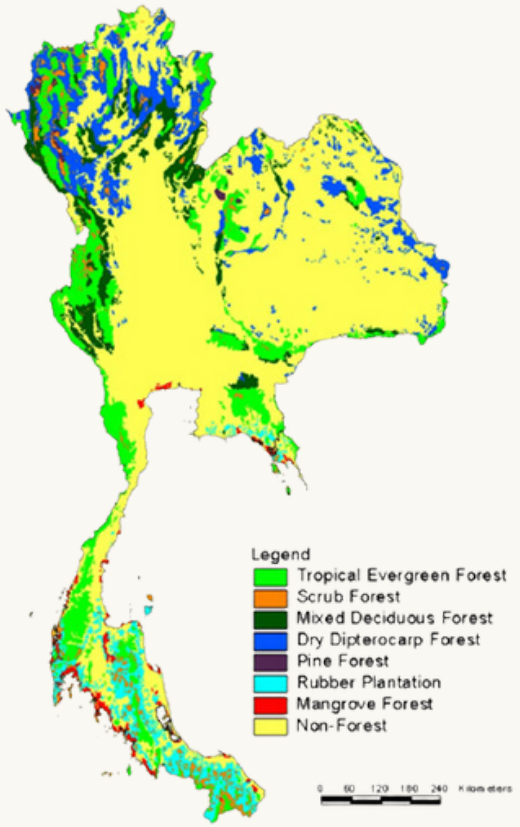
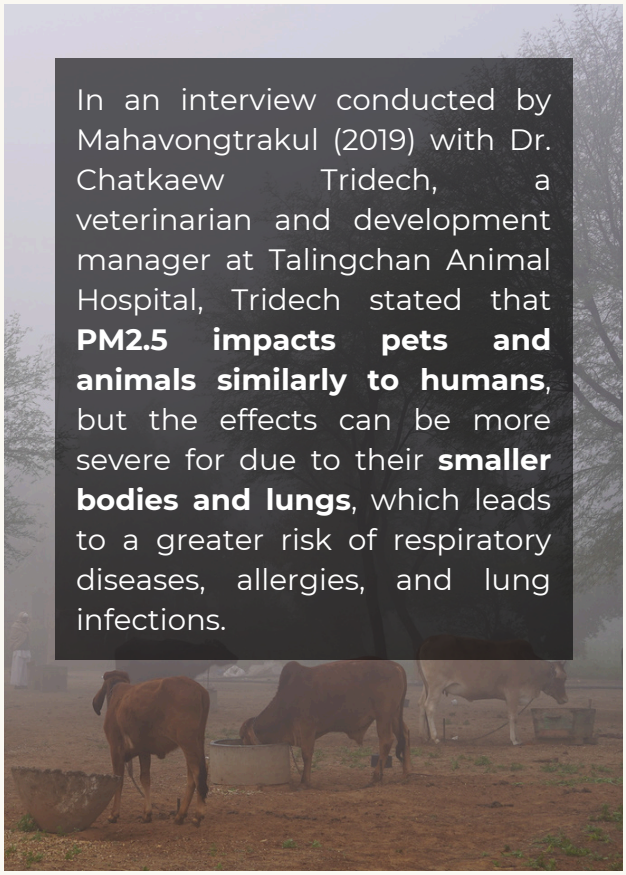



**Fig. 15.** Forest classification map of Thailand. (Source: Beaver & Lan-Yu)



In an interview conducted by Mahavongtrakul (2019) with Dr. Chatkaew Tridech, a veterinarian and development manager at Talingchan Animal Hospital, Tridech stated that **PM2.5 impacts pets and animals similarly to humans**, but the effects can be more severe for due to their **smaller bodies and lungs**, which leads to a greater risk of respiratory diseases, allergies, and lung infections.

Image credit | Shimbhustock/Getty Images

Plant leaves are the primary receptors for gaseous pollutants and PM. The intensity of PM2.5 effects varies on the exposure: short-term exposure leads to acute injury, which results in the death of leaves or entire plants, whereas long-term exposure causes chronic injury where the symptoms are not immediately apparent, such as stunted growth, yellowing, and reduced overall plant growth (Rai, 2016; Roy et al., 2024).

The accumulation of PM on plant leaves can alter its optical properties since sunlight is blocked from reaching the chloroplasts in the leaves, which reduces photosynthesis, and ultimately leads to reduced plant growth and yields.

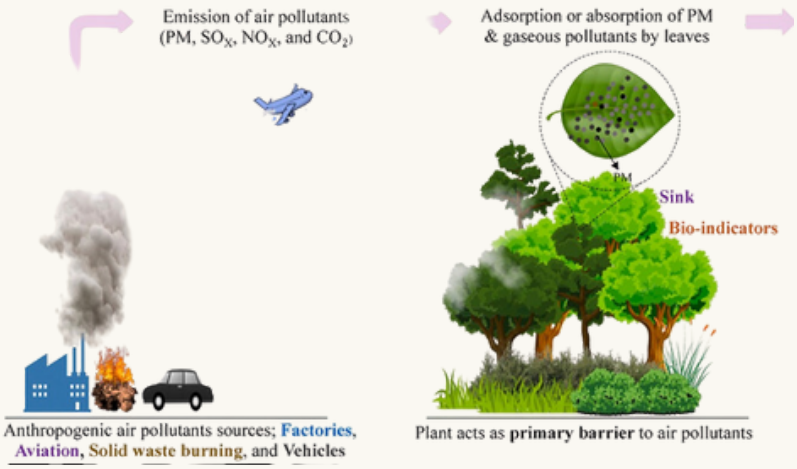



**Fig. 16.** Plants as air pollution sinks.
(Source: Tripathi & Nema)

## iii. Impact on climate change

The atmosphere contains a mixture of different PM types that can influence global warming depending on the composition and contains both warming and cooling effects. PM not only contributes to air pollution, but affects Earth's radiation as well (Chen et al., 2021). In general, **light-colored particles**, like sulfates, act as mirrors which reflect and scatter sunlight back into space before light can reach the Earth's surface, which reduces the solar energy that warms the planet and creates a **cooling effect**. On the other hand, **dark particles**, such as black carbon, will absorb radiation and heat the surrounding air, which contributes to **warming**. If PM settles on ice or snow, this causes the surface to darken and absorb more heat from the sun, and therefore speeds up the melting process (Clarity, 2022; IQAir, 2022).



Image credit | Vold77/Getty Images

**Black carbon (BC)**, a component of fine PM, is one of the largest contributors to global warming behind carbon dioxide (CO2). It is produced through the **incomplete combustion of fossil fuels and biofuels** (i.e. wood) and has severe negative effects on the climate.

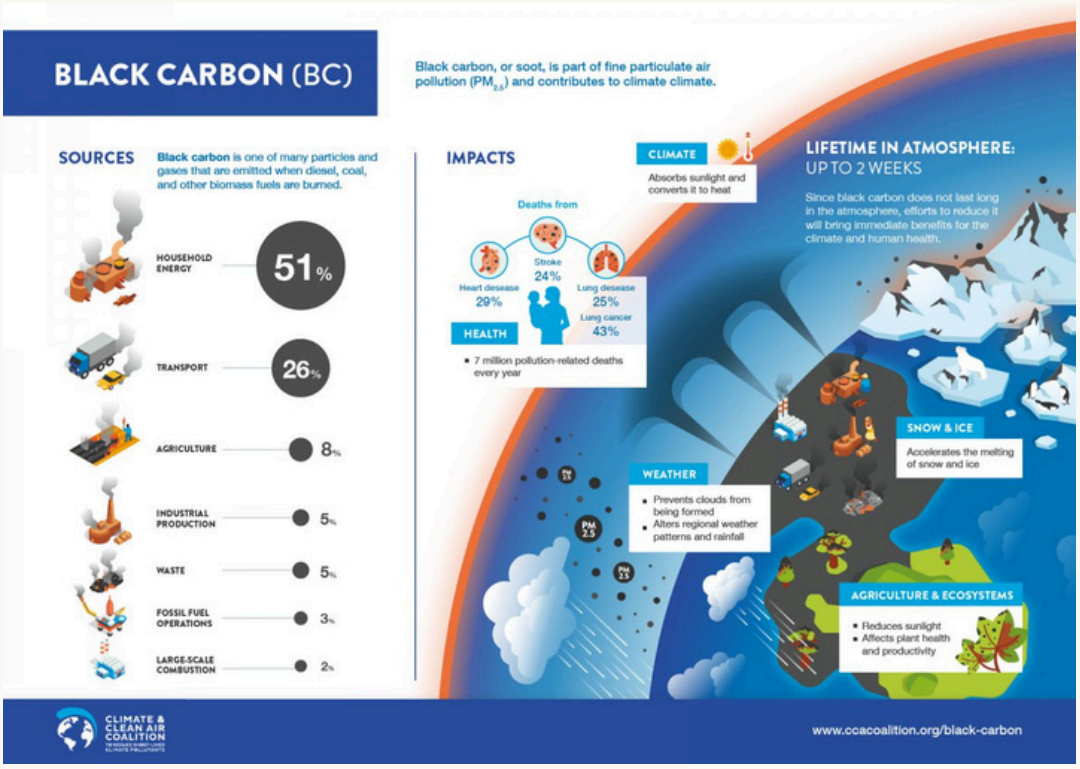



**Fig. 17.** Sources of black carbon.
(Source: Climate and Clear Coalition)

According to the Climate and Clean Air Coalition, the warming impact of BC is about **460-1,500 times more potent than CO2** on a per-unit mass basis. Although BC remains in the atmosphere for a short period and returns to the Earth's surface within days or weeks via rain or snow, this PM can absorb a considerable amount of solar radiation. This absorption traps heat in the atmosphere and leads to substantial environmental damage, which includes the acceleration of snow and ice melt, the disruption of normal weather patterns, and adverse effects on agricultural and ecosystem health (Clarity, 2022; WHO, n.d.).

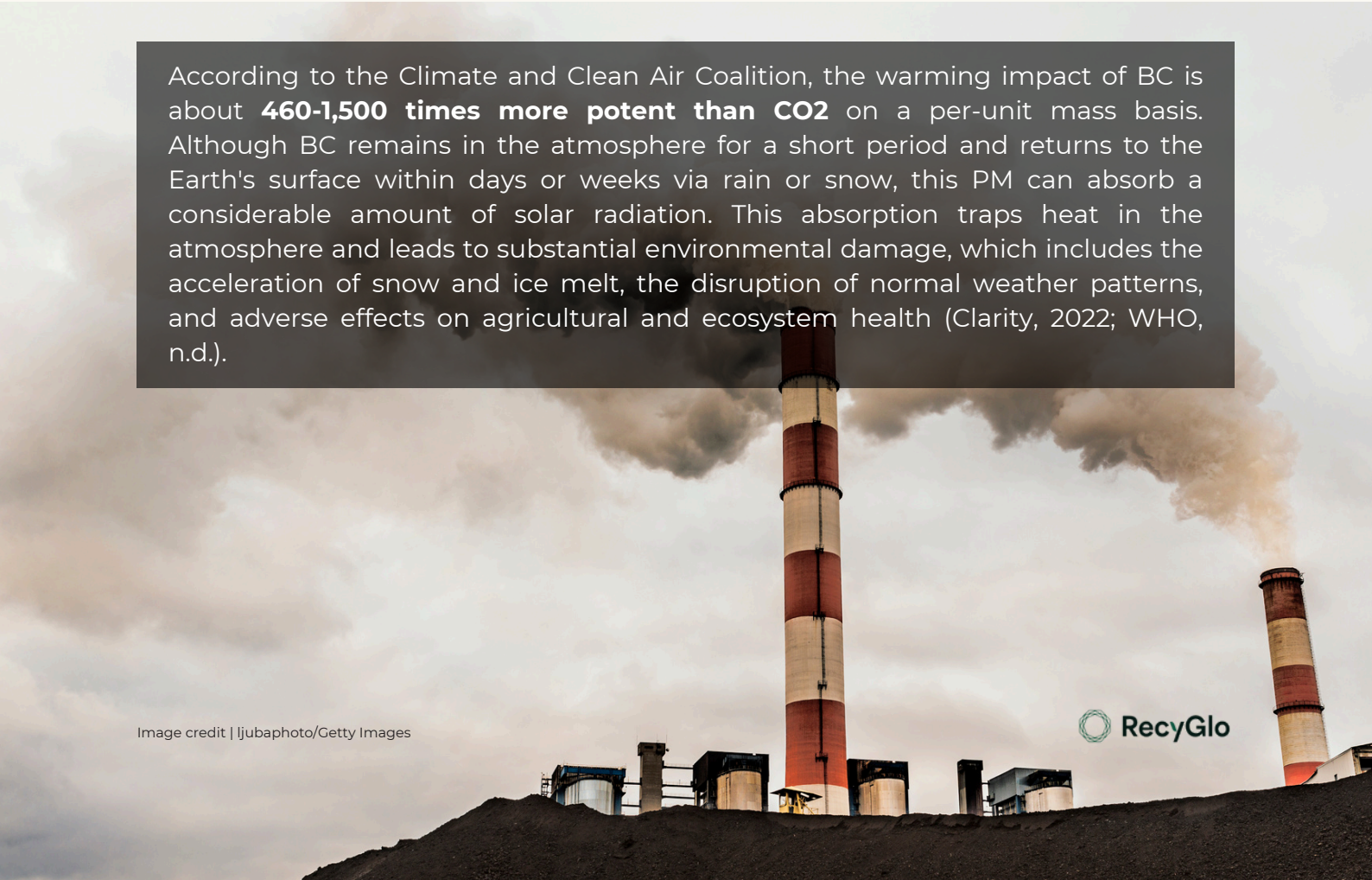


Image credit | ljubaphoto/Getty Images

RecyGlo

# SOCIO-ECONOMIC IMPACT

## Tourism

The tourism sector is essential to Thailand. Within the last 10 years, Thailand has experienced a significant growth in tourism that **contributes directly to the country's GDP** which surged from 5.3% in 2009 to 12.3% in 2018 (Praditthong et al., 2022). The number of tourists increased from 29,923,185 in 2015 to 39,916,251 in 2019, or a cumulative 33.4% increase within a 5-year period (Fig. ABC).


**Fig. 18.** Total tourists that visited Thailand in 2015-2019. (Adapted from Ministry of Tourism and Sports)


Notably, Thailand saw a large increase in the number of **Chinese tourists** in the third quarter of 2019 (Ministry of Tourism and Sports, 2020). In 2020 and 2021, the tourism sector took a massive nosedive due to the **COVID-19 pandemic** and **stringent travel rules** that were put in place, yet the country has made an impressive recovery since then (Fig. 18).

From January to July 2024, Thailand saw the greatest number of tourist arrivals from **China, Malaysia, India, Republic of Korea, and The Russian Federation**. Although these numbers have yet to return to pre-pandemic figures, the amount of visitors from these countries to Thailand remains relatively high.

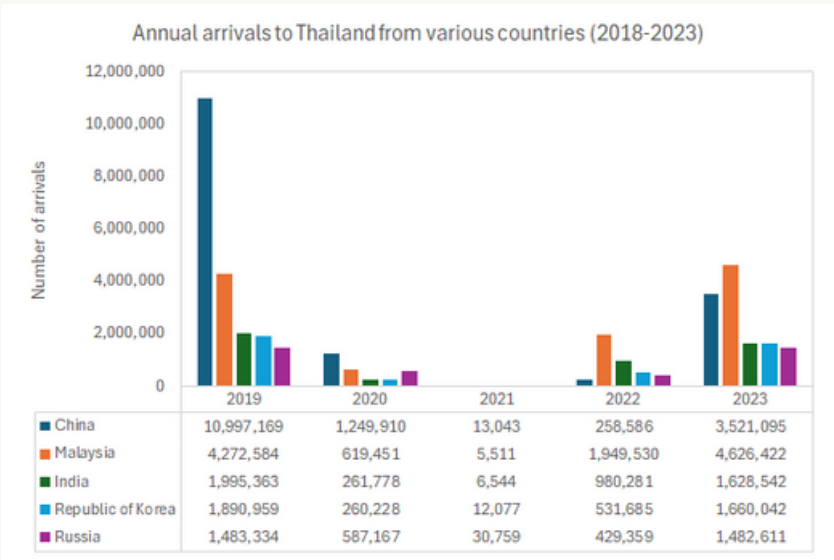



**Fig. 19.** Annual arrival of travelers from various countries to Thailand. (Adapted from Ministry of Tourism and Sports)



Image credits | DAPA Images

Northern Thailand is a popular travel destination for local and international tourists. The region houses 17 different provinces such as Chiang Mai, Phrae, and Lamphun which have many attractive locations to visit and explore. However, during the cool season of recent years, the region has become infamous for its poor air quality and PM2.5 problems among local and international news.

In March 2024, the PM2.5 levels in Chiang Mai were reported to be hazardous and highly unsafe for outdoor activity, which affected the general population in the province. However, the government at the time **did not curb tourism** promotions and activities in the northern province despite protests from opposition political parties to **declare Chiang Mai as a disaster zone** for the people's health and safety. Former Prime Minister Srettha Thavisin expressed that declaring Chiang Mai as a disaster zone might discourage and prevent international tourists from visiting Thailand, which was crucial since the country's tourism sector had just recovered from the negative impacts of the worldwide COVID-19 pandemic (Cogan, 2024; Shoowong, 2024).

Despite great government efforts to boost tourism, it was reported that Chiang Mai did not see a resurgence in tourist arrivals and activities in the month of April 2024 when **Songkran** celebrations (Thai New Year) were scheduled to take place. This was primarily attributed to the **negative impacts of PM2.5 pollution that largely affected the tourism sector in Chiang Mai** (The Nation Thailand, 2024). Although the government was heavily criticized for putting the public's safety at risk in order to re-stimulate the post-COVID tourism sector, Fig. 20 illustrates the positive growth in the total number of tourists that visited Chiang Mai and Northern Thailand in 2024 compared to 2023 for the months of January to July.


**Fig. 20.** Comparison of visitors to Chiang Mai and Northern Thailand in 2023 and 2024, during January to July. (Adapted from Ministry of Tourism and Sports)

Image credit | Veerasak Piyawatanakul/Getty Images

# Health

Air pollution caused by human activities and natural sources (i.e. vehicle and industrial emissions, agricultural residue burning, biomass burning, and forest fires) pose **significant health risks** (Boogaard et al. 2019; WHO, 2022). In 2016, it is estimated that ambient **outdoor air pollution was responsible for 4.2 million premature deaths** globally in urban and rural areas (WHO, 2022).

In Northern Thailand, the health impacts of air pollution are evident, particularly concerning **lung cancer** and **respiratory diseases**. The incidence of lung cancer among Northern Thai women is among the highest in Asia, with an annual age-adjusted rate of 37.4 per 100,000 (Pongpiachan et al., 2013). Research by Pongpiachan & Paowa (2015) found a significant **increase in hospital walk-ins and admissions** during the haze season, especially among **children** under 15 years old, which highlights their vulnerability to respiratory diseases. Other studies show that children attending schools near pollution hotspots have a higher prevalence of respiratory conditions like **rhinitis** and **atopic dermatitis** compared to those in less polluted areas (Sriyaraj et al., 2008).

Moreover, evidence suggests that during haze episodes, the levels of **urinary 1-hydroxypyrene – a biomarker of exposure to polycyclic aromatic hydrocarbons (PAHs) – in Northern Thai schoolchildren are significantly higher** (4 to 10 times greater) than in schoolchildren from other parts of Thailand including Bangkok (Naksen et al., 2017). These findings highlight the severe health impacts of air pollution in Northern Thailand, particularly for vulnerable populations such as women and children, and emphasize the need for effective air quality management strategies to protect public health.

## Economic impact on livelihoods

Another significant impact of PM2.5 on the livelihoods of individuals in Northern Thailand is its effect on the local economy. As previously discussed, the **tourism and healthcare sectors** are particularly hard-hit by PM2.5 pollution. Tourist numbers drop during periods of high pollution, which leads to **decreased tourism-related spending**. Meanwhile, the healthcare sector sees an increase in hospitalizations due to respiratory illnesses, forcing patients to **allocate more of their finances toward medical expenses**. This dual impact strains both local businesses and household budgets and further highlights the economic challenges posed by PM2.5.




A health economic impact assessment by the PCD (2018) shows that the reduction of PM10 and PM2.5 concentrations in Chiang Mai to WHO Interim Target 1 levels could lower the total health benefits, valued at **1.86 billion THB** in 2017. Further reductions to WHO Interim Target 2 levels would result in health benefits totaling to **2.09 billion THB**, and achieving WHO Interim Target 3 levels would bring **2.13 billion THB**. If air concentrations were reduced below the WHO guidelines, the total economic health benefits for Chiang Mai are estimated at 2.18 billion THB (PCD, 2018).

**Investment in cleaner air** not only improves public health, but **reduces future healthcare costs and provides savings** as well. This highlights the value of prioritizing air quality improvements for both economic and health benefits.

As the Thai government takes urgent actions to recover financially, economically, and socially, the World Bank Group (2021) claims that the country has a unique chance to build more sustainable, inclusive, and resilient economies. Recovery efforts, both short- and long-term, should **focus on investments that create jobs and stimulate economic activity, enhance human, social, and natural capital, protect biodiversity and ecosystem services, increase resilience, and promote the decarbonization of economies**.

# GOVERNMENT EFFORTS TO REDUCE PM2.5

## Fines and laws

Thailand's current system to manage air quality involves several laws that address air pollution monitoring and treatment and to set air quality standards. Various government agencies, like the Ministry of Natural Resources and Environment (MONRE), the Ministry of Industry, and the Ministry of Public Health, oversee air quality. **However, there is no law specifically dedicated to air quality control** (Lekfuangfu et al., 2024).

The new **Clean Air Bill** in Thailand aims to provide a complete approach to manage and reduce air pollution from various sources that include factories, vehicles, open burning, and pollution from neighboring countries (Lekfuangfu et al., 2024). It also includes economic incentives to encourage both businesses and individuals to help reduce pollution.

**Key features** of the new Clean Air Bill include:

- **Citizen Rights:** The bill ensures that the government will provide important information about air pollution and offer free healthcare to those affected by it. It also allows citizens to participate in policy-making and plan implementation related to air quality.
- **Air Quality Standards and Pollution Control:** A new Management Committee for Clean Air will set air quality standards and oversee pollution sources. According to Lekfuangfu et al. (2024), the PCD will be given the authority to monitor air quality and report annually. MONRE and the Ministry of Interior will supervise air quality improvement plans.
- **Regulation of Pollution Sources**: Owners of pollution sources must install systems to control emissions. If they fail to meet standards, they may face fines up to **THB 50,000.** Open burning is banned unless approved by the provincial governor, and MONRE will set the guidelines to manage emissions.

Image credit | Thai court: gangliu/Getty Images
Forest: 200mm/Getty Images

The bill also addresses transboundary air pollution which requires cooperation with other countries and international organizations. Those responsible for pollution from outside of Thailand could face **fines up to THB 50 million**. Additionally, the bill introduces economic tools like clean air taxes, treatment charges, and subsidies to promote cleaner air practices (Lekfuangfu et al., 2024). Nonetheless, legal avenues can still be exercised through the judiciary system and relevant laws such as the Enhancement and Conservation of the National Environmental Quality Act.

In upholding the rule of law, it was reported that the **Chiang Mai Administrative Court has ruled against the previous Prime Minister and the National Environment Board (NEB) for negligence of duty and sluggishness to perform their duty to address the PM2.5 situation in Northern Thailand** (Bangkok Tribune, 2024). The Prime Minister at that time was Gen Prayut Chan-o-cha and the previous chairman of the NEB was Deputy PM Gen Prawit Wongsuwan. They were accused by the plaintiffs, which included legal, medical, and civil practitioners and advocates, who had filed a joint petition which instructed concerned agencies to do more in order to tackle the PM2.5 situation. The group accused them of failing to enforce their authority to a full extent. Although the court has sentenced both individuals, Thailand has experienced several political changes since the ruling which make it difficult to impose. Nonetheless, prevention and awareness efforts continue to the public which will be discussed in the next section.

*Doi Inthanon National Park, Chiang Mai*

*Chiang Dao, Chiang Mai*

Image credit | Lemaret Pierrick/Getty Images

## Prevention and awareness

Forest fires in Northern Thailand cannot be managed and resolved by a single government agency. Hence, it is important for everyone to **collaborate in order to manage, control, and prevent wild forest fires.** The "Forest Fire and Haze Resolution Network" was established with over 61 networks in Chiang Mai. These networks are in Mae Taeng, Chiang Dao, Muang, Hang Dong, Chom Thong, Mae Rim, Phrao, and Suthep districts (Department of National Parks, Wildlife and Plant Conservation, 2023; Khunthong et al., 2024).

The local government has also introduced **programmes to support smallholder farmers by offering subsidies**. For instance, sugarcane farmers can obtain subsidies if they manage to produce “good quality fresh sugarcanes” that are free from burning or contamination. In order to combat the burning in Chiang Rai, Breuning (2023) reported that Lt. Dujdeaw Wongpak, Head of the Chiang Rai Provincial Agricultural Office, introduced the “**Chiang Rai Zero Burn Model**” to participants.

“Air pollution is a major issue faced by people in Chiang Rai. The province is committed through the...Zero Burn Model (to solve) the problem by reducing burning and supporting farmers to manage their rice straw,” Wongpak said. The same model can be applied to its neighboring province, Chiang Mai.

Palakhamarn (2023) reported that ASEAN plans to run **training programs that can help enhance the skills of regional officials to better address cross-border haze issues.** Chiang Mai was chosen as the training site to share Thailand's expertise in forest fire management with the other ASEAN countries. The program is structured to strengthen the capabilities of government officials in wildfire management and combines academic knowledge, advanced skills, as well as practical and virtual field training. However, since this initiative is exclusive to high-level officers, more local awareness and training is required to collectively manage waste and minimize open burning effectively.



Image credit | Gajus Images

## Case studies from other countries

The early stages of the **ASEAN Agreement on Transboundary Haze Pollution (AATHP)** – which Thailand, Laos, Myanmar are signatories to – was met with **resistance**. In particular, ***Indonesia refused to ratify the agreement and questioned the effectiveness of regional efforts to address the issue***. The year 2006 saw severe haze pollution that significantly impacted the populations and economies of affected countries.

The governments of Singapore and Malaysia ***shifted from pressuring Indonesia to offering assistance and wildfire management instead***. Meanwhile, public movements at the national, regional, and international levels raised awareness about the sources and dangers of haze pollution and applied pressure on Indonesia. These efforts succeeded in 2014, after 12 years, as Indonesia became the last ASEAN member to sign the agreement (Fongissara & Buddharaksa, 2022).

After 3 years of reduced haze due to COVID-19 restrictions, the **transboundary haze worsened** in 2023 largely due to the El Niño weather pattern that affected **Indonesia**, **Malaysia**, and **Singapore**.

Malaysia was particularly outspoken, with its environment minister, Nik Nazmi, who ***urged Indonesia to address the situation***. However, Indonesian officials denied that the haze originated from their country. Despite the back-and-forth tensions, Malaysia recorded an unhealthy Air Pollution Index (API) of 158 in late September, while Indonesia had an API beyond 300 in South Sumatra. The severe pollution forced both countries to consider online classes and issue health warnings to the general public.

Although regional agreements such as the **AATHP** or **Regional Haze Action Plan (RHAP)** promote joint action between countries, the ***efforts have not resolved underlying political issues.*** **ASEAN countries need stronger domestic laws to address the transboundary haze and end the ongoing blame game** (Mai, 2023). For Thailand's proposed Clean Air Bill, Kongsawad (2024) reported that the bill contains a provision that calls for **greater cooperation to tackle the transboundary haze.**

The Indonesian government is often criticized by Singapore and Malaysia with regards to the generation of haze. However**, some of the plantations responsible for the open burning of organic waste are linked to groups based in Singapore and Malaysia** (Reuters, 2019).

The Indonesian government **identified companies affiliated to Malaysia,** such as IOI, Genting, and KLK, as well as those linked to Singapore which include Bumitama and Musim Mas (Greenpeace Southeast Asia, 2019).

Indonesia's Environment Minister, Siti Nurbaya Bakar, mentioned that some of the **fires** in Indonesia occurred in **palm oil plantations** owned by subsidiaries of Malaysian companies (Greenpeace Southeast Asia, 2019). The plantations were sealed off after fires were detected. In response to these actions, Malaysia's Primary Industries Minister, Teresa Kok, expressed concern that the Indonesian government attempted to target Malaysian-owned concessions, and stated that "the named Malaysian companies are among the most respected oil palm cultivators." She also voiced her worry that ***these accusations could fuel anti-palm oil campaigns*** (Povera, 2019).

As discussed, most governments within ASEAN have been upfront to resolve the transboundary haze crisis. Therefore, **Thailand needs to play a more dominant role in engaging with neighboring governments to find a middle ground in resolving this issue.**



Image credits | Forest fire: Dmytro Gilitukha/Getty Images,
Palm oil plantation: Rich Carey/Getty Images

# STRATEGIES TO REDUCE PM2.5 THROUGH ORGANIC WASTE MANAGEMENT

Upon identifying the root causes of PM2.5, such as the open burning of organic waste and the transboundary haze pollution, this section offers several **recommendations**. This includes policy-level suggestions, strategies for businesses and farmers, and opportunities for NGOs and academics to raise awareness and share their expertise in order to minimize the impact of PM2.5 in Northern Thailand.

## Introduce more stringent environmental policies and regulations

As pointed out above, farmer representatives stated that there is a **lack of legal enforcement** from local authorities (Breunig, 2023). Therefore, while clearer legal guidelines are under development, such as the Clean Air Bill, government authorities can still enforce existing regulations. For example, Article 9 under the Enhancement and Conservation of the National Environmental Quality Act gives full power to a prime minister to solve environmental crises.

On top of that, the government should introduce more stringent environmental policies. This includes **banning the use of chemical fertilizers**. For example, Sri Lanka and Australia banned the import of chemical fertilizers. Currently, organic fertilizers are available in the Thai market, however, the production remains low and is deemed inadequate to meet commercial demands.

As reported by The Nation Thailand (2022), The Chemical Industries Club of the Federation of Thai Industries (FTI), academics, and farmers have urged the government to lift the ban on certain chemical herbicides and pesticides to meet commercial demands and enable Thailand to achieve its objective in becoming the “kitchen of the world”.

Image credits | PM2.5: Mas042/Getty Images,
Organic fertilizer: okugawa/Getty Images

## Sustainable waste management practices

There are several ways in which sustainable waste management practices can be implemented to address the issue of organic waste. Majority of farmers are unaware of the advantages of utilization of organic wastes and often burn them in open air which contributes to air pollution. Organic waste is a biodegradable waste which can naturally decompose and managing them sustainably can provide several benefits where these practices will not only improve environmental outcomes but also offer considerable financial benefits compared to traditional waste disposal methods.

## Composting

Composting is **a sustainable and eco-friendly way to manage organic waste**. It involves breaking down organic materials, like food scraps, yard waste, animal manure, paper, and textiles, under controlled conditions to produce compost, **a nutrient-rich material that improves soil quality** (Jenks2026, 2024). This method effectively recycles organic waste into a product that **enhances soil health, supporting the natural biological cycle** (Pajura, 2024).

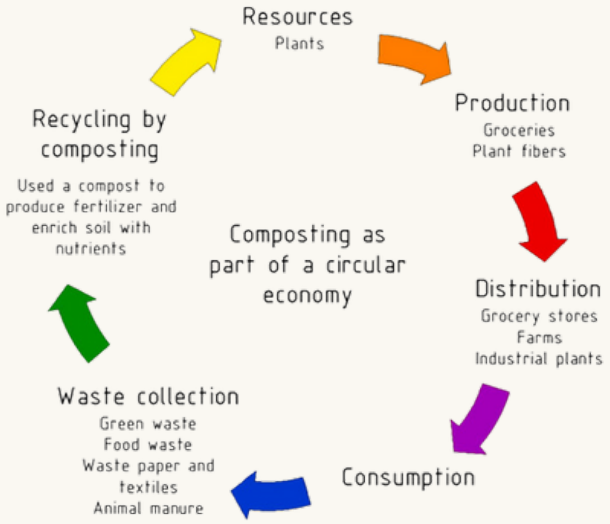



**Fig. 21.** Composting as part of a circular economy (Source: Pajura)

Composting relies on aerobic microorganisms to break down organic matter, producing a stable compound rich in beneficial substances that can be used to improve soil in agriculture, gardens, and public green spaces. Composting can be done at various scales, from small home setups to large industrial operations. It's a **cost-effective solution compared to other waste management methods** and is often used in environmental education projects due to its simplicity and easy application in schools, businesses, and households (Teixeira et al., 2020).

Using biocompost has a positive impact on both soil health and plant growth. **(Amouei et al., 2020) showed that compost-based fertilizers help enrich agricultural soil** while reducing heavy metal levels, lowering the risk of contamination and providing environmental and farming benefits. Composting offers key advantages, such as **minimizing waste and reducing the need for landfills** and moreover, it is a much **more affordable method of waste management compared to incineration**, due to lower operating and setup costs (Le Pera et al., 2022; Sekito et al., 2019). Recent events, including the COVID-19 pandemic and global conflicts, have led to a rise in fertilizer prices due to supply chain disruptions (Sridhar et al., 2023). Therefore, producing nutrient-rich compost not only helps manage waste but also creates a valuable product that improves soil quality and boosts crop yields, providing dual benefits to both agriculture and the environment.


On the other hand, composting can take considerable time and requires good planning, as the typical **process lasts over 1–2 months**. This extended time frame can limit its broader use (Siedt et al., 2021). Another challenge with composting is dealing with **odors and pests**. If **compost piles aren't properly managed** with the right mix of materials, they can **produce unpleasant smells** and if **compost bins aren't well sealed**, they may **attract pests like rodents or flies**. The practicality of composting as a waste management solution depends on the situation as some people argue that it requires a lot of space, resources, and infrastructure, making large-scale implementation difficult (Jenks2026, 2024).



Image credit | Xeero.io

## Biochar

Biochar is the carbon and ash-rich material left behind after biomass undergoes pyrolysis. It is **a stable, carbon-rich substance that can remain in the soil for thousands of years without breaking down**. When applied to soil, biochar can **greatly improve the health of soil ecosystems** where it helps improve soil structure, boosts water retention, and increases nutrient availability. Due to its **porous structure, biochar also enhances soil aeration, reducing compaction and supporting better root growth** (Manikandan et al., 2023). It is particularly useful in improving the fertility of acidic soils, leading to higher crop yields. Moreover, **biochar's ability to capture and store carbon makes it a valuable tool** in combating climate change (Wakefield, n.d.). By improving soil quality, promoting nutrient cycling, and supporting plant growth, biochar contributes to sustainable agriculture while helping reduce environmental impacts.

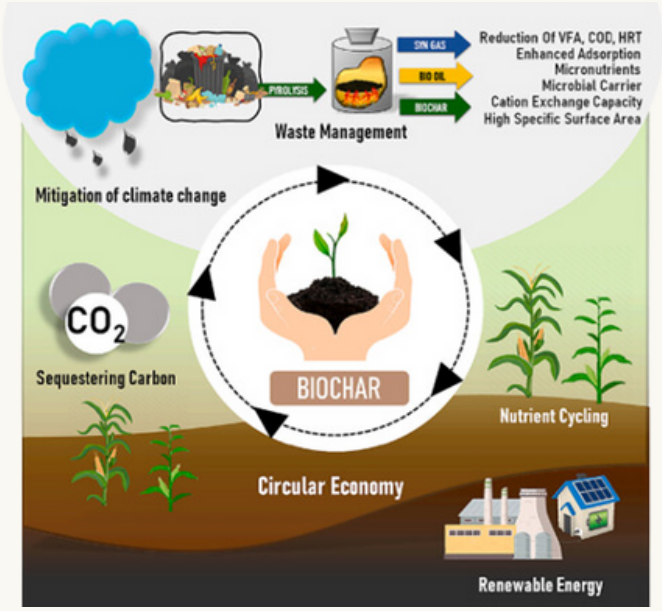
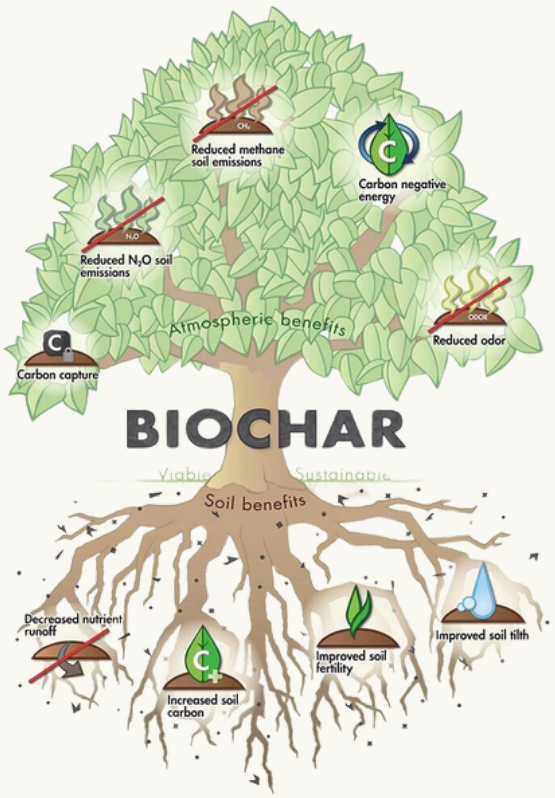



**Fig. 22.** Biochar as part of a circular economy (Source: Manikandan et al.)

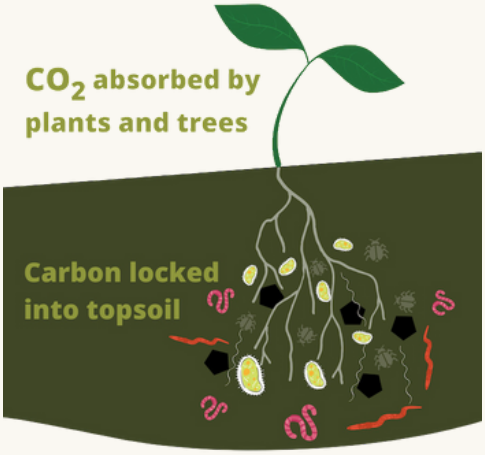



Soils amended with biochar have shown an improved **ability to retain water, helping plants cope with dry conditions by reducing water stress** (Rasa et al., 2018). This benefit is particularly important for future agriculture, which will face more frequent droughts due to climate change. **Biochar's porous structure**, along with the spaces between the biochar and soil particles, **helps trap and store water** (Barnes et al., 2014). **Agegnehu et al. (2015) conducted a field study in northern Queensland,** Australia, where **biochar** made from waste willow wood was **applied to soil**, leading to a **23% increase in peanut production**.



Image credit | EESI

However, the **sustainability of biochar largely depends on the feedstock material** and its **ability to sequester carbon**, which can **vary from low to high** (Siedt et al., 2021). In leading countries, most biochar is produced in gasifiers, where temperatures range from 200 to 800°C in the buffer zone and 800 to 1,000°C in the combustion zone during pyrolysis. While **the production process consumes a lot of energy and directly burning biomass releases CO2**, **pyrolysis or gasification converts the carbon in biomass into biochar, which can then be stored in soil** because it acts as a carbon sink, storing carbon and **preventing it from being released into the atmosphere** (Khadem et al., 2021).




## Biochar as a catalyst in composting process

The incorporation of additional feedstock materials into composting process such as biochar or bacterial inoculation can also have a positive impact on the final product and its maturation time (Pajura, 2024).

A literature review by Guo et al. (2020) found that **adding biochar during composting reduced unpleasant odors, greenhouse gas emissions, and volatile organic compounds**. It also enhanced the airflow within the compost and minimized nitrogen loss. This reduction in emissions is due to biochar's porous structure, which improves aeration and water retention. Moreover, recent studies have shown that **biochar enhances the humification process, making compost more effective**. It also **boosts microbial activity** and decreases the presence of heavy metals and organic pollutants (Behera & Samal, 2022; Nguyen et al., 2022).

Verma et al. (2023) found that **adding biochar from wheat straw influenced the microbial community at different stages of composting**, improving both the quality and maturity of compost made from food waste. The study highlighted that the best results for compost maturity were achieved with 15% biochar. As the biochar content increased, so did the germination index. **Compost was considered mature once the germination index surpassed 50%, which occurred between 14 and 21 days with 15% biochar, and continued to improve afterward.**

Image credit | biochar.co.uk

## Community engagement and awareness

It is undeniable that a well-informed public can play an important role to lessen PM2.5 levels. Therefore, it is essential to intensify efforts to **engage directly with communities** through **knowledge-sharing and awareness activities**. However, while increased awareness and more coordinated efforts between Thailand, Laos, and Myanmar to address the haze problem is a step in the right direction, it is unlikely to result in a swift solution due to low government effectiveness in Laos and Myanmar (Fongissara & Buddharaksa, 2022). Hence, the **Thai government** should take the lead to support the GMS. As illustrated by Fongissara & Buddharaksa (2022), ***Singapore and Malaysia shifted their approach from pressuring Indonesia to providing assistance and aid.*** The Thai government could adopt similar strategies by leveraging the resources and expertise available in the country. For instance, several environmental foundations and international chambers of commerce have collaborated to offer support in mitigating the PM2.5 issue. The government should capitalize on these opportunities to enhance community engagement and raise awareness effectively.

**Academics** can play a crucial role by engaging with farmers through knowledge-sharing and technology transfer. For example, in Southern Thailand, Onphakdee (2023) reported that **Walailak University** organized an online Annual International Training Course on Good Air Quality using PM2.5 sensors and the Internet of Things (IoT).

This course aimed to raise awareness, impart knowledge and management skills, and share the best practices to control and mitigate PM2.5, in order to ultimately reduce health risks and improve the quality of life. Meanwhile, **Chiang Mai University** has introduced **@aircmu**, a dust monitoring and air quality system available through the LINE messaging app, which has over 50 million users in Thailand. In addition to its monitoring features, @aircmu provides interactive knowledge and news related to air pollution, leveraging insights from academic professionals (Pintapluk, 2023).

However, many community engagement and awareness activities rely heavily on a top-down approach, which often *fails to integrate local knowledge effectively in mitigating environmental issues*. In contrast, **Sarawak**, one of the states in Malaysia most affected by transboundary haze, has introduced a **Disaster Risk Management Training program for the local community** (Sarok & Nizam, 2019). This program extends beyond formal education in schools and universities through the incorporation of traditional wisdom and local knowledge for protection against natural hazards. It also emphasizes the active involvement of mass media. Adopting a similar approach in Thailand could enhance the effectiveness of efforts to address environmental challenges and ensures that solutions are both **culturally resonant** and **community-driven** at the same time.



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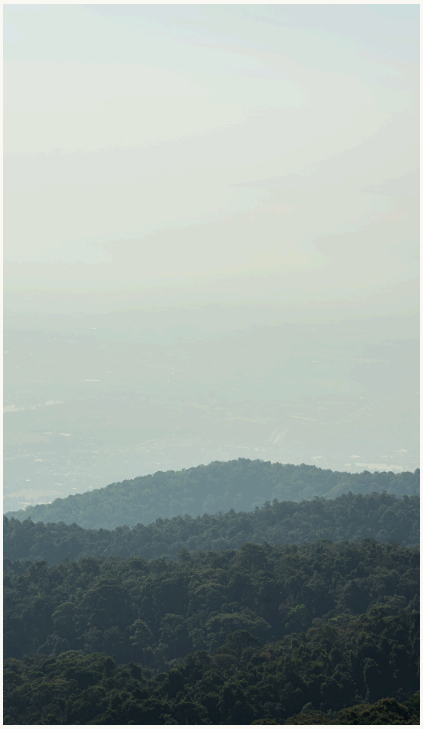


# CONCLUSION

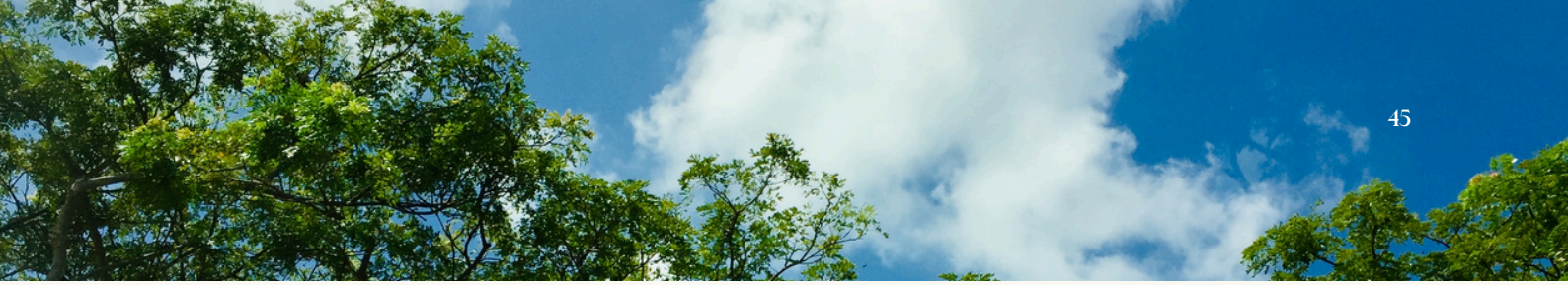
In conclusion, tackling the PM2.5 pollution issue in Thailand requires a comprehensive approach that involves **collaboration from various stakeholders**. This review has identified several **key sources of PM2.5** in Northern Thailand, which include the open burning of organic waste, forest fires, increased corn farming, insufficient forest cover, and transboundary haze pollution. Even though there have been efforts like the ASEAN Haze Regional Agreements to address this issue, transboundary haze continues to affect countries like Thailand, Malaysia, and Singapore. The review also highlights that some **companies involved in contract farming** for crops like corn and palm oil in other countries contribute to forest fires, which in turn cause haze that spreads across borders and impacts these nations.

The PM2.5 pollution has had serious consequences for both the **environment** and the **socio-economic** conditions in Thailand. Environmentally, the degradation of air quality has led to harmful effects on ecosystems, biodiversity, and has contributed to climate change. On the socio-economic side, the impact has been felt in areas such as tourism, public health, and the overall economy, particularly the effect on people's livelihoods. In response, the Thai government has initiated various measures to reduce PM2.5 levels, such as **raising public awareness, providing training, and enforcing legal measures**. At a regional level, ASEAN has also taken steps to mitigate transboundary haze through the introduction of **cooperation agreements** aimed to reduce PM2.5 issues.

This review also explores different strategies to reduce PM2.5 levels, with a particular focus to **improve the management of organic waste**. There is a clear need for the Thai government to implement stricter environmental policies and regulations, such as the New Clean Air Bill, which is currently under consideration. Additionally, more **sustainable waste management practices** should be adopted not only by local farmers but also by **individuals**. Regular community engagement and awareness campaigns should be conducted year-round, rather than only during peak pollution seasons.

**RecyGlo Thailand** believes that the root cause of PM2.5 pollution lies in the **mismanagement of organic waste**, and emphasizes that a more sustainable and effective approach must be adopted to address this issue.

Image credits | Valentina Nitu





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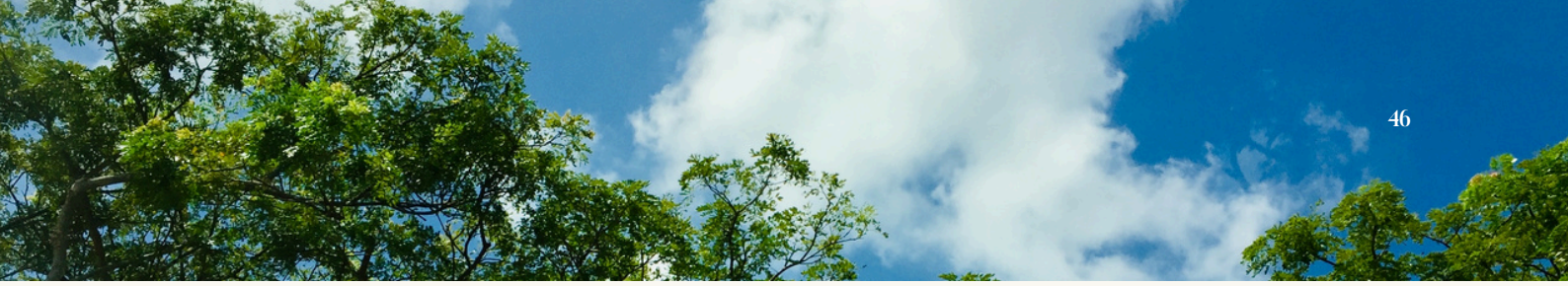



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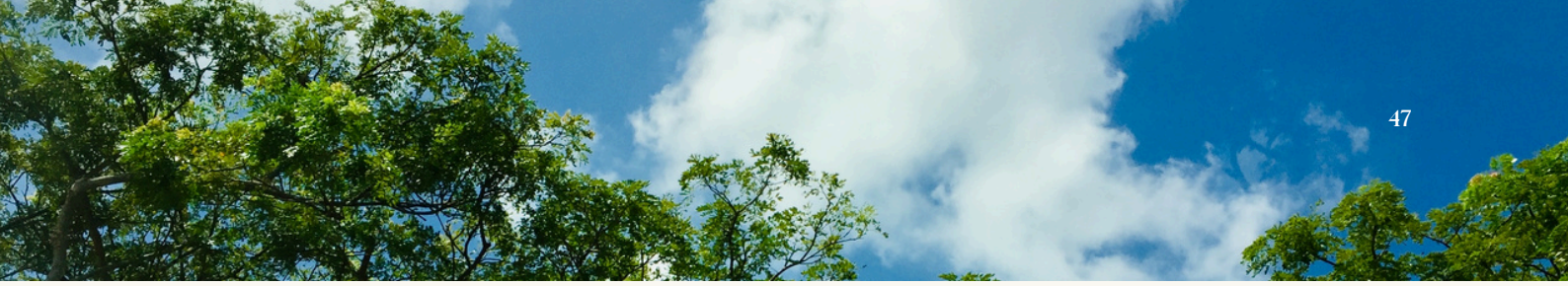



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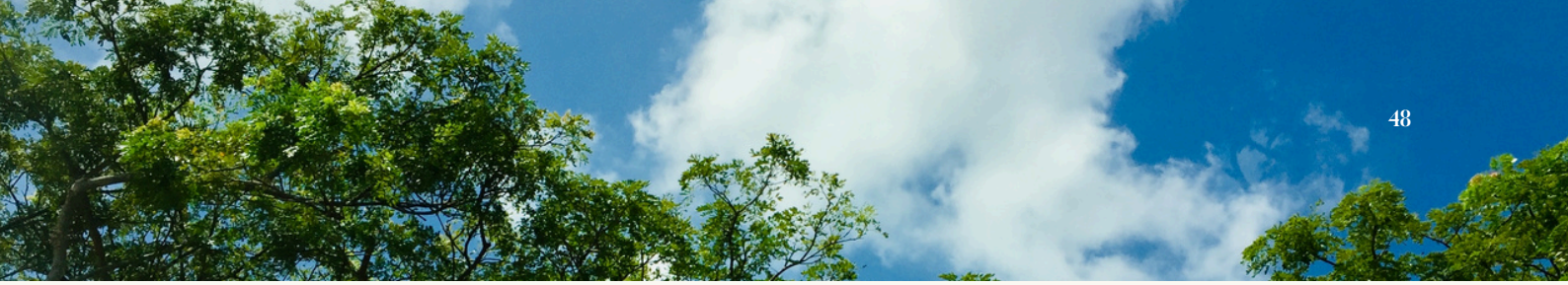



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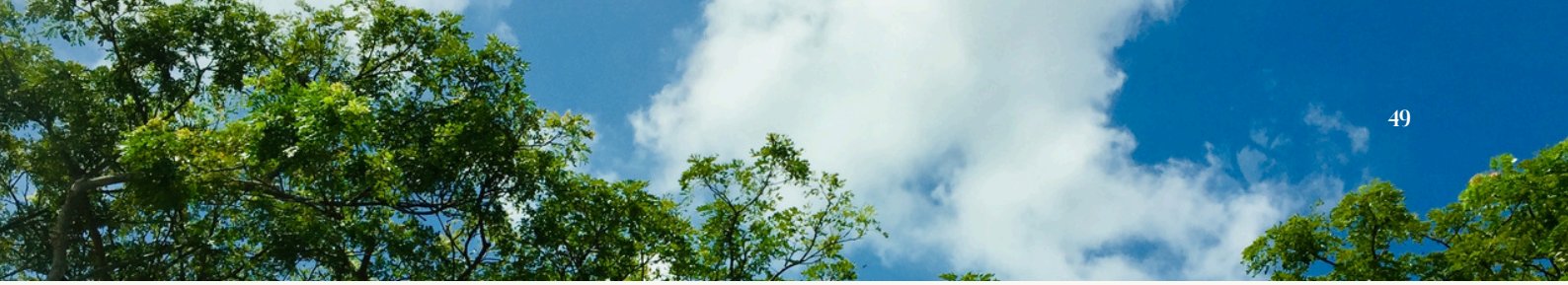



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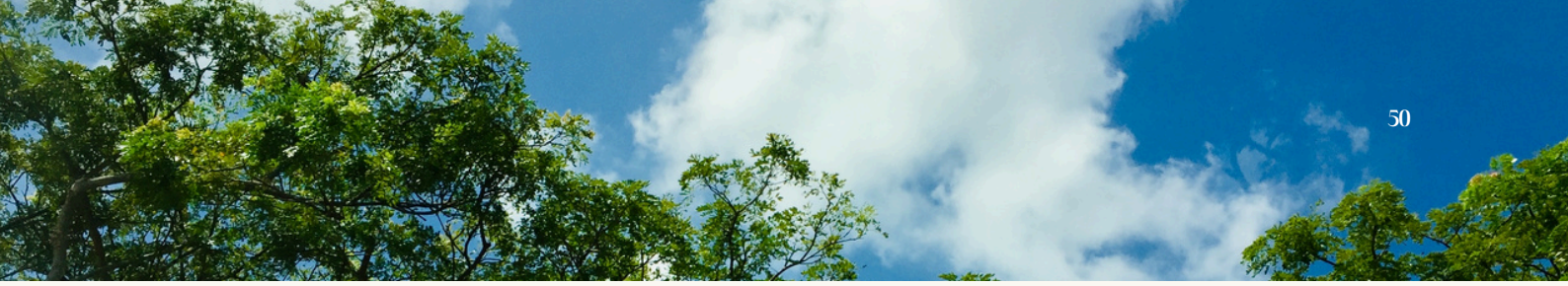



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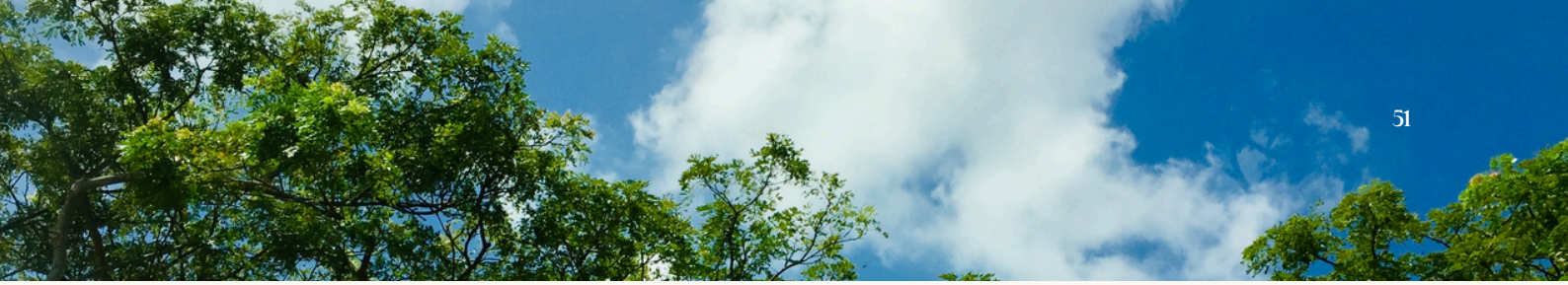



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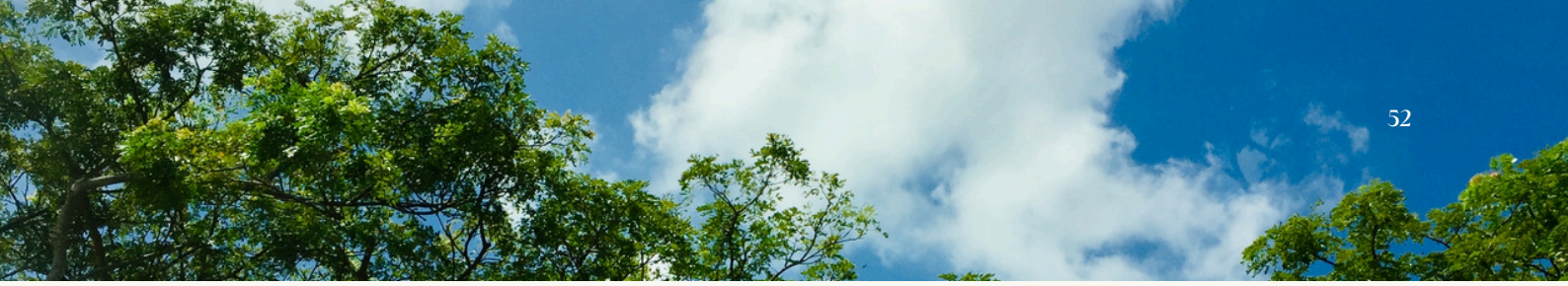



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