

Performance Audit on the Implementation of the National Agenda Plan for Particulate Matter (PM2.5) Mitigation

Preventing and Reducing Open Burning in
Sugarcane Cultivation Areas

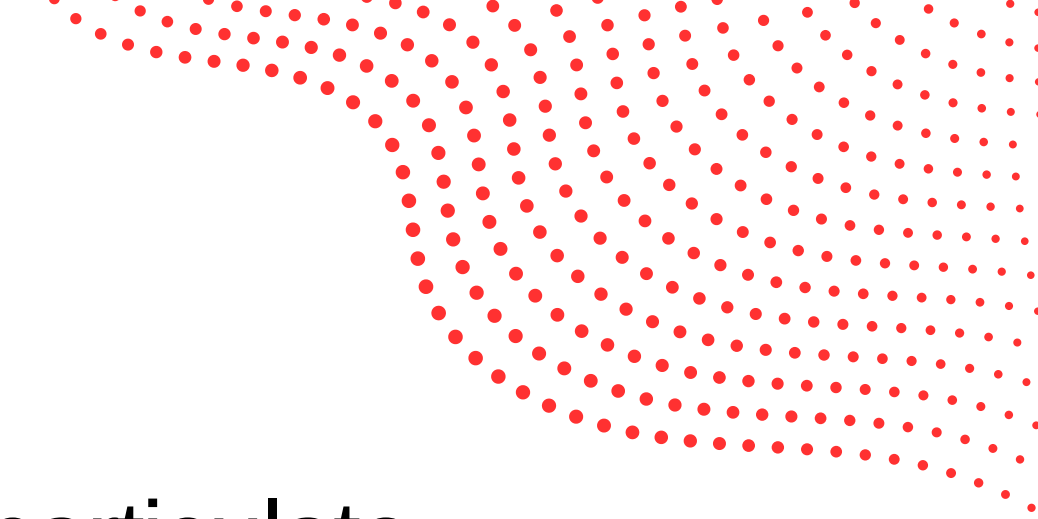


**State Audit Office of
the Kingdom of Thailand**





Reason and Importance



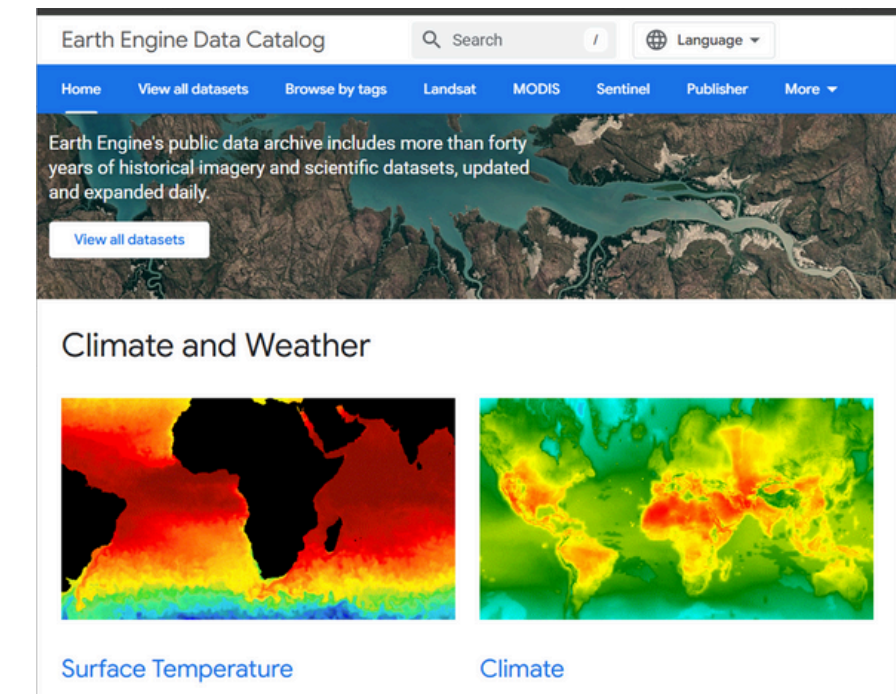
- Thailand has long faced the problem of particulate matter (PM) pollution.
- Since 2019, the Thai government has launched the National Agenda Plan for Particulate Matter (PM) mitigation.
- One major source is open burning in sugarcane fields, commonly burned before harvest to reduce cost.
- The government has allocated over 25 billion baht to phase out burnt sugarcane by the 2023/2024 crop year.



Source of Data

Analysis of Particulate Matter (PM 2.5) and Fire Hot Spot Situation

- PM2.5 data, estimated from Aerosol Optical Depth (AOD) from 2000 to 2024 were analyzed using the Google Earth Engine (GEE) platform, which provides satellite-derived datasets.
- PM2.5 data, Ground-based air quality data were sourced from the Pollution Control Department (PCD) monitoring stations.
- Fire Hotspot data, indicating thermal anomalies, were collected using VIIRS sensors onboard JPSS NOAA-20 (J1), JPSS NOAA-21 (J2), and SUOMI-NPP satellites, supported by the Fire Information for Resource Management System (FIRMS) operated by NASA.



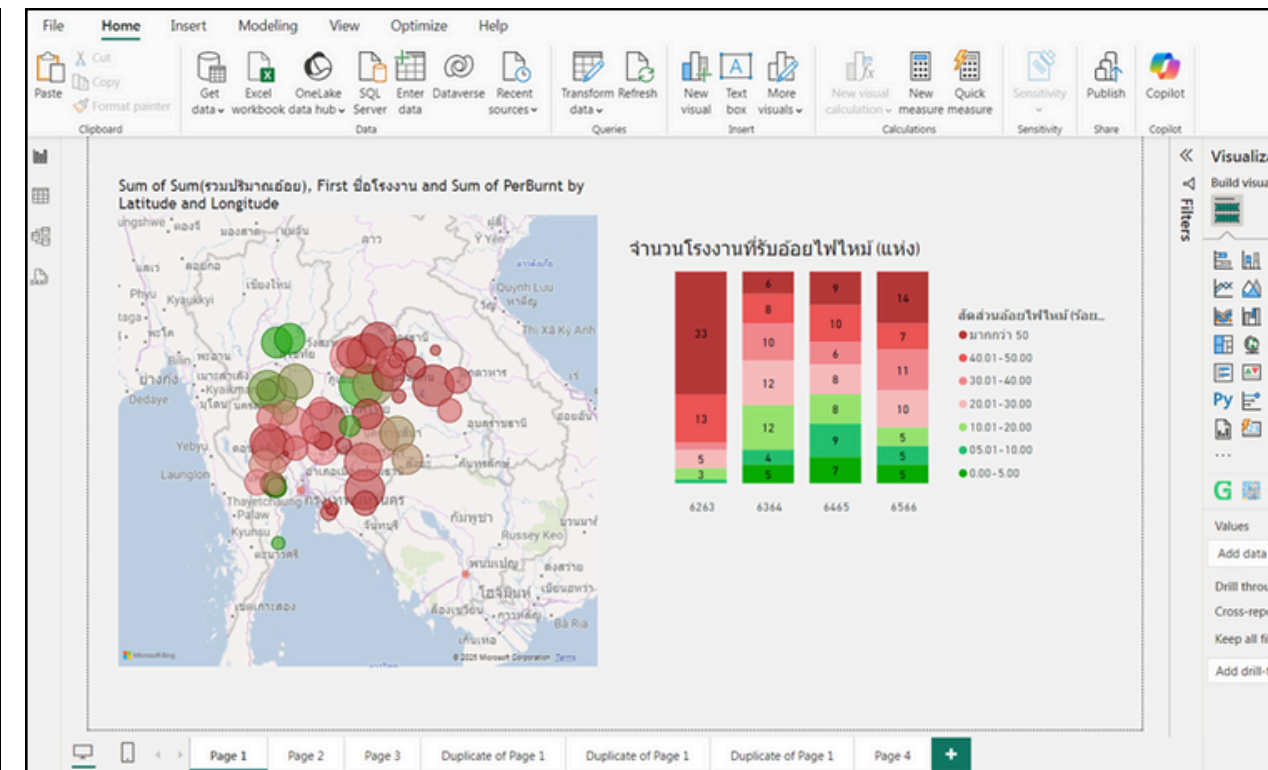
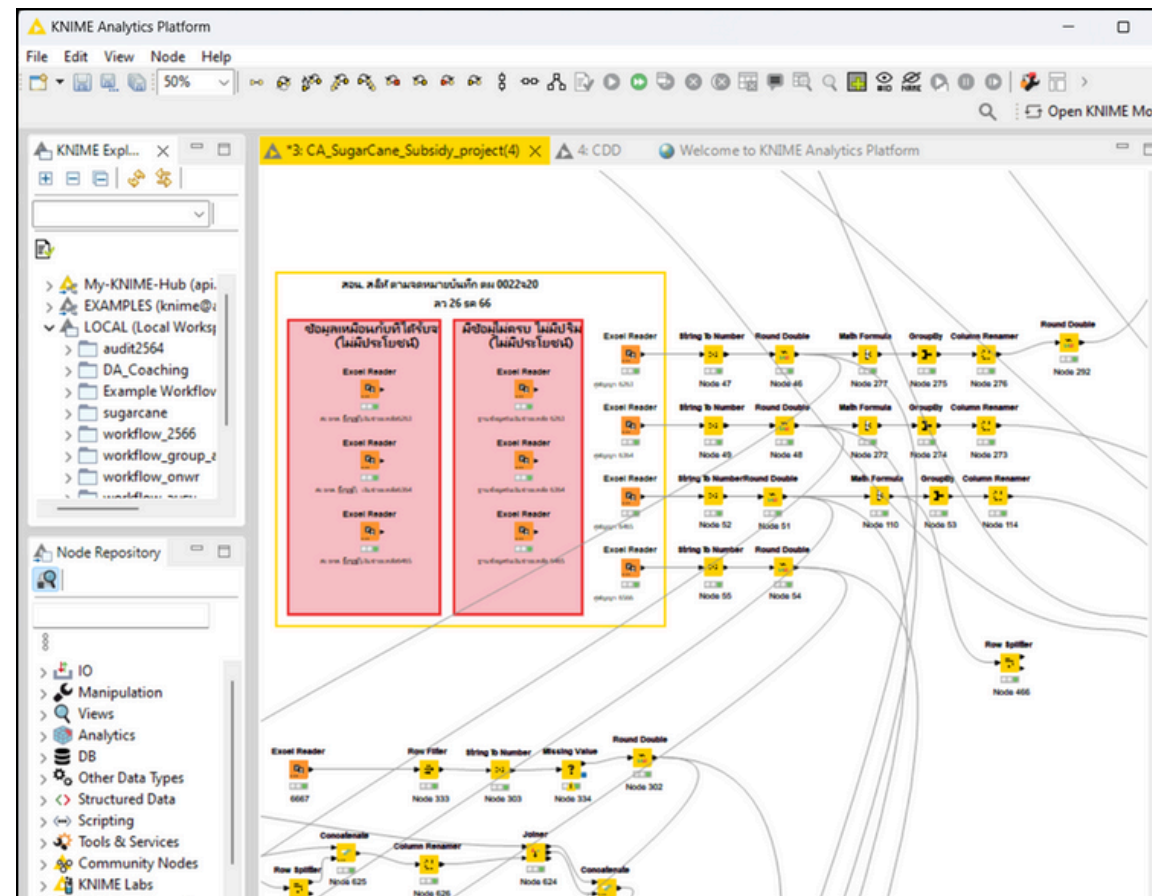
Source of Data

Analysis of Burning Reduction in Sugarcane Cultivation

- Land use maps at 1:25,000 scale, provided by the Land Use Policy and Planning Division, Land Development Department
- Farmer's sugarcane delivery data and official sugar production reports, from crop years 2012/2013 to 2023/2024
- Payment records under the financial support program for farmers delivering fresh (non-burnt) sugarcane, from crop years 2019/2020 to 2021/2022



Data analysis tool



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In [1]: import pandas as pd
import numpy as np
from sklearn.model_selection import StratifiedKFold
from sklearn.ensemble import RandomForestClassifier, GradientBoostingClassifier, VotingClassifier,
StackingClassifier
from sklearn.linear_model import LogisticRegression
from xgboost import XGBClassifier
from lightgbm import LGBMClassifier
from catboost import CatBoostClassifier
from sklearn.metrics import accuracy_score, classification_report, confusion_matrix, roc_auc_score,
precision_score, recall_score, f1_score

# 1. โหลดข้อมูล
data_path = r"sugarcane_data.csv"
df = pd.read_csv(data_path)

# 2. กำหนดตัวแปรต้นและตัวแปรเป้าหมาย
X = df.drop(columns=['target_0', 'no_cane_year_target'])
y = df['target_0']

# 3. จัดการค่าที่เป็น NaN
X = X.fillna(X.median())

# 4. ตรวจสอบ Outliers และตัดขอบบน-ขอบล่าง 1%
for col in X.columns:
    lower_bound = X[col].quantile(0.01)
    upper_bound = X[col].quantile(0.99)
    X = X[(X[col] >= lower_bound) & (X[col] <= upper_bound)]

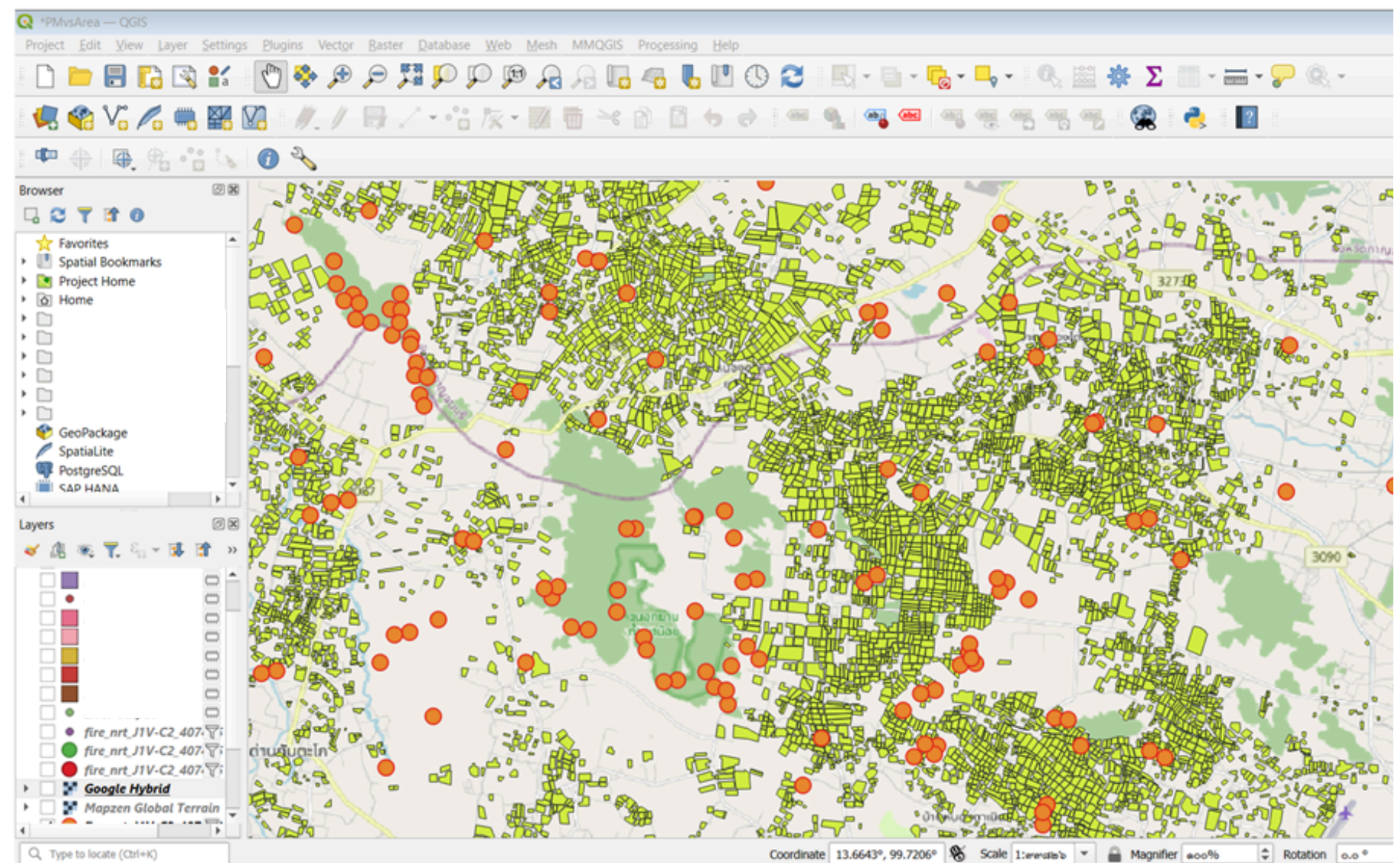
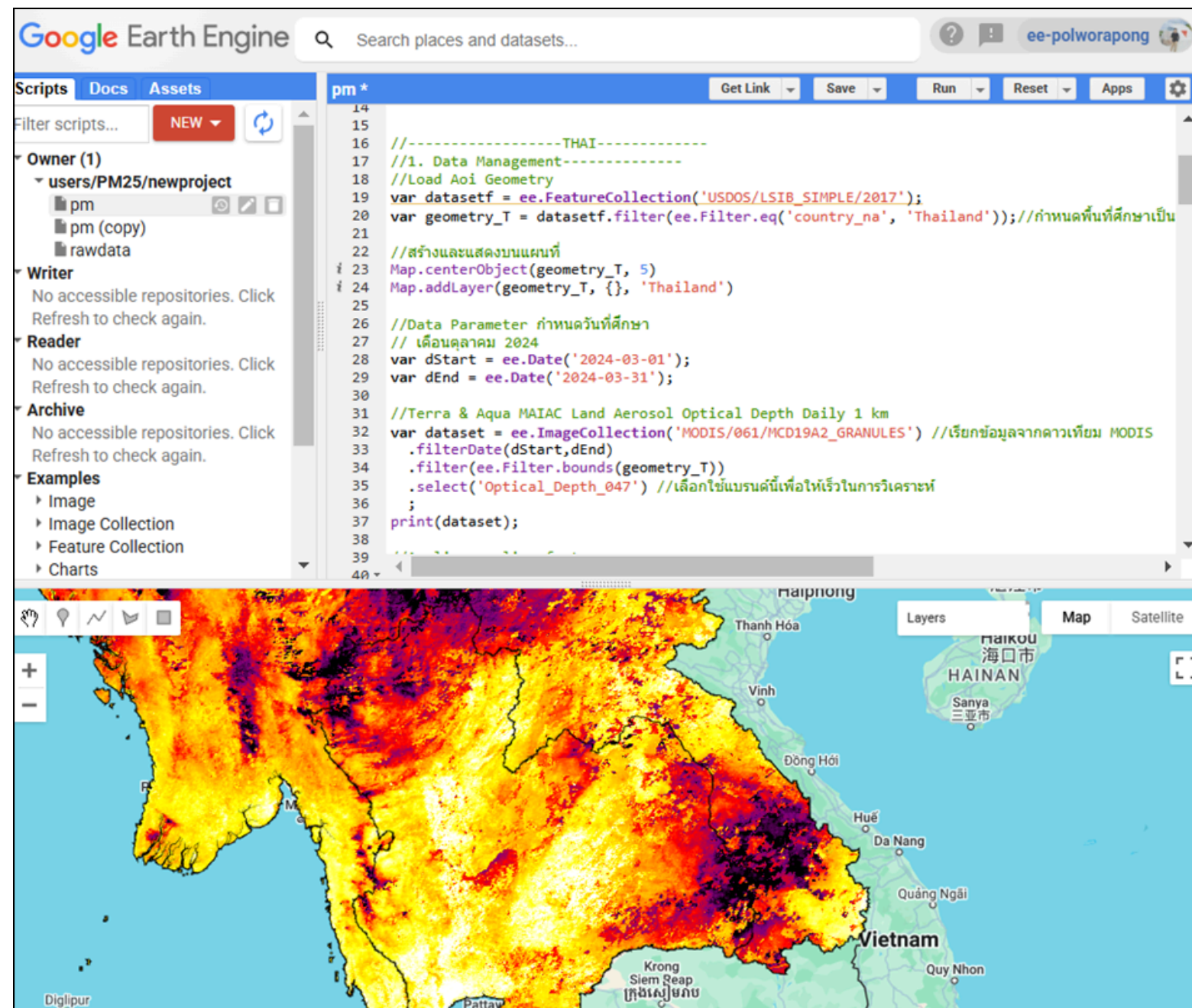
y = y.loc[X.index]

# 5. สร้างโมเดล
rf_clf = RandomForestClassifier(n_estimators=300, random_state=42)
gb_clf = GradientBoostingClassifier(n_estimators=300, random_state=42)
xgb_clf = XGBClassifier(use_label_encoder=False, eval_metric='logloss', random_state=42)
lgb_clf = LGBMClassifier(n_estimators=300, random_state=42)
cat_clf = CatBoostClassifier(silent=True, random_state=42)
lr_clf = LogisticRegression(max_iter=1000, random_state=42)

voting_clf = VotingClassifier(estimators=[
    ('rf', rf_clf),
    ('gb', gb_clf),
    ('xgb', xgb_clf),
    ('lgb', lgb_clf),
    ('cat', cat_clf)
], voting='soft')
```


Data analysis tool

Google Earth Engine javascript





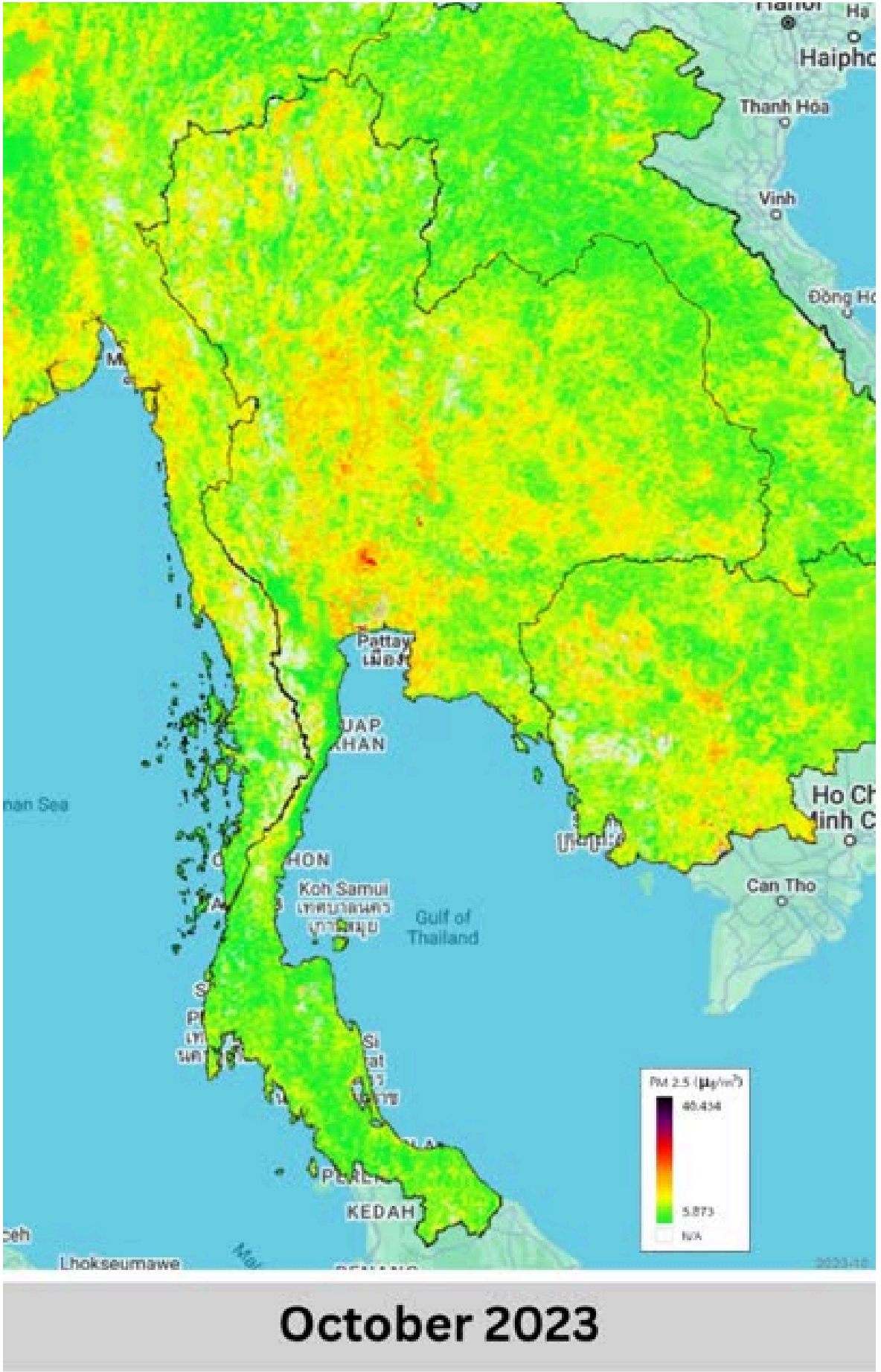
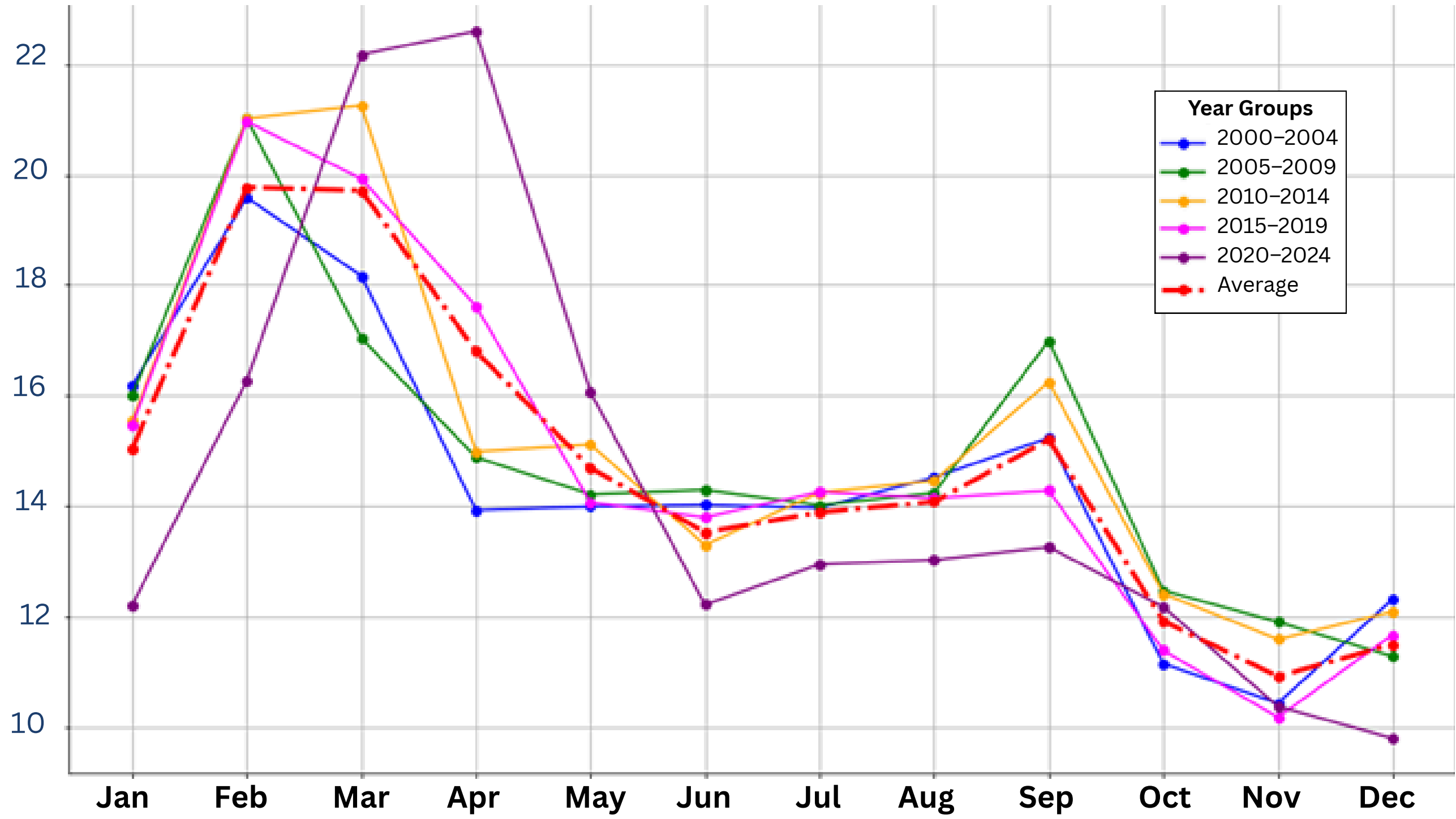
Data Analytics Results

- The Trend of PM2.5 and burning (fire hot spot) problems
- The situation of sugarcane burning and the behavior of farmers after subsidy receiving
 - Apply the **Churn Analysis** to examine individual farmer's behavior after receiving supports, the proportion of burnt cane continues to decrease?
- Key factors for reducing PM2.5 (burning) in sugarcane cultivation areas
 - Machine Learning (Classification Supervisor)
 - Analysis of Variance (ANOVA)



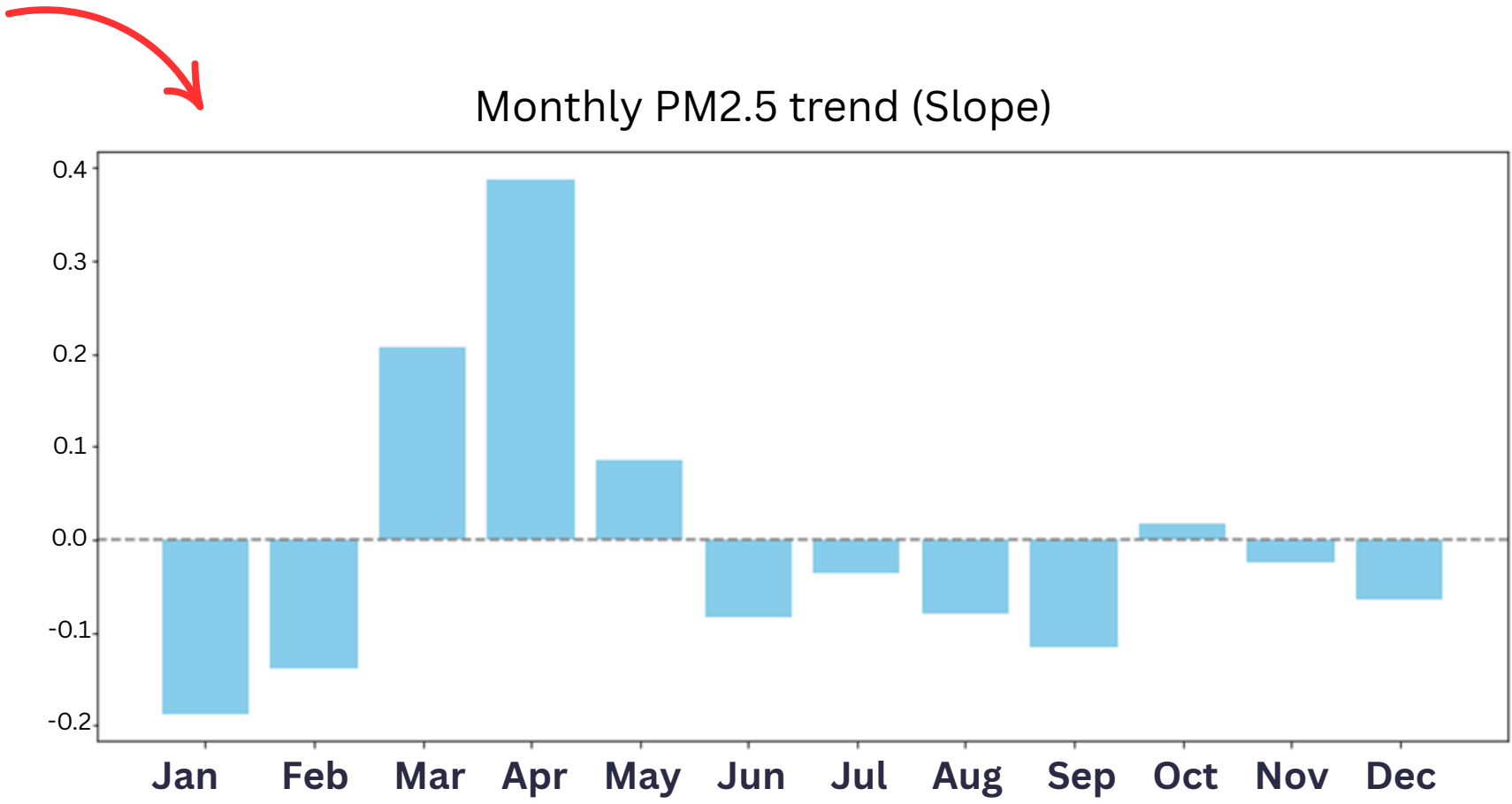
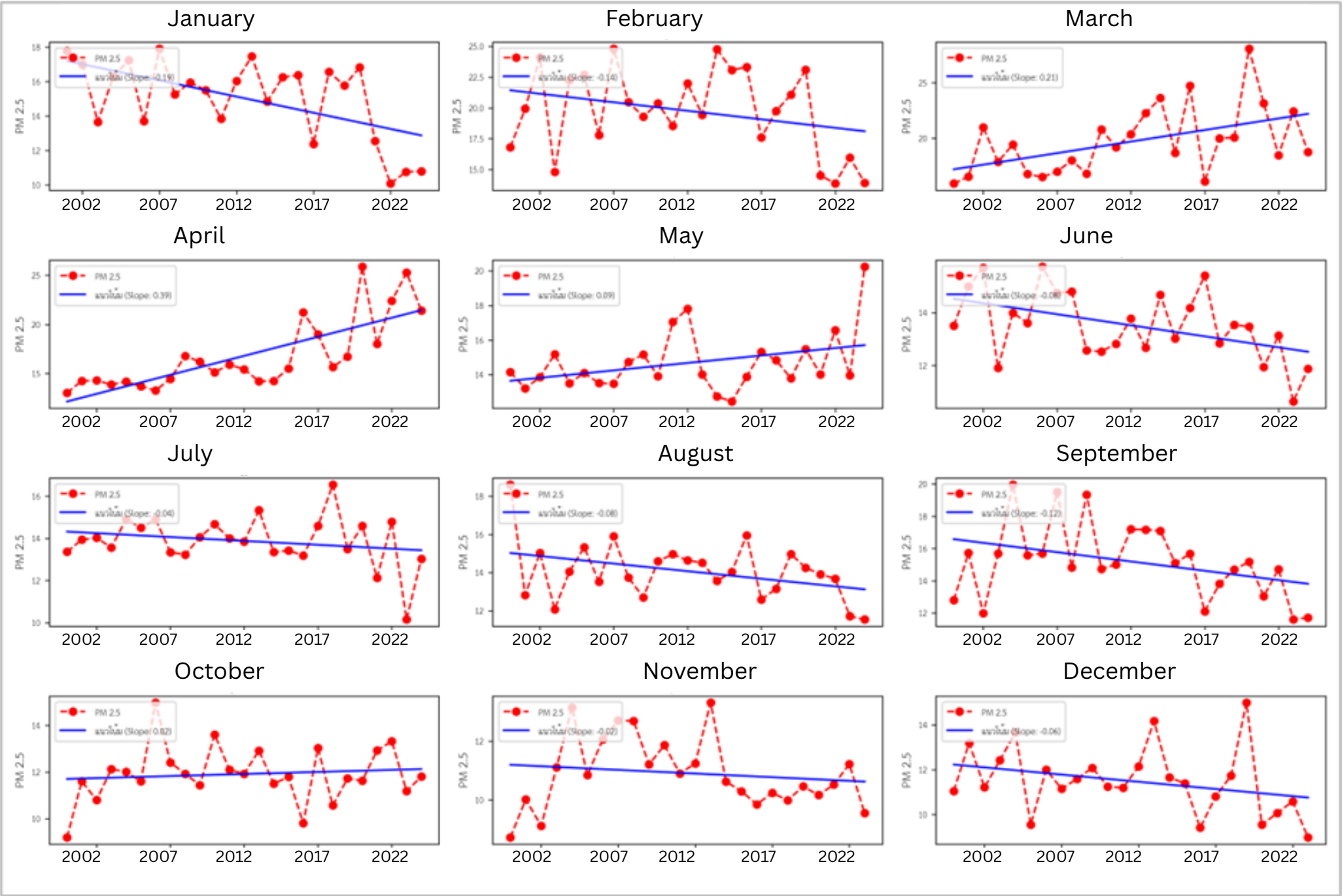
Concentration of fine particulate matter (PM2.5 level) ●●●

Estimated from Aerosol Optical Depth data from 2000 - 2024 (25 yrs)



Concentration of fine particulate matter (PM2.5 level)

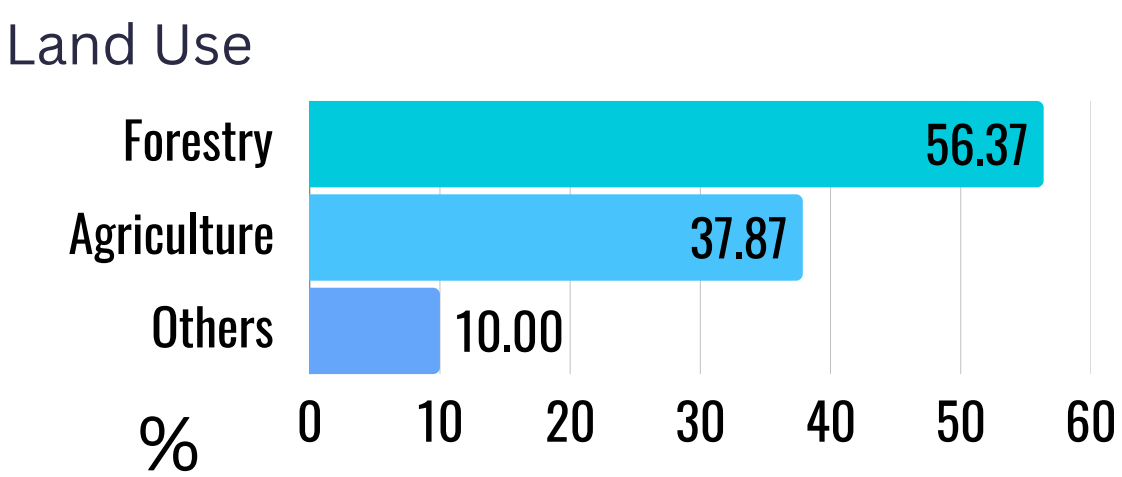
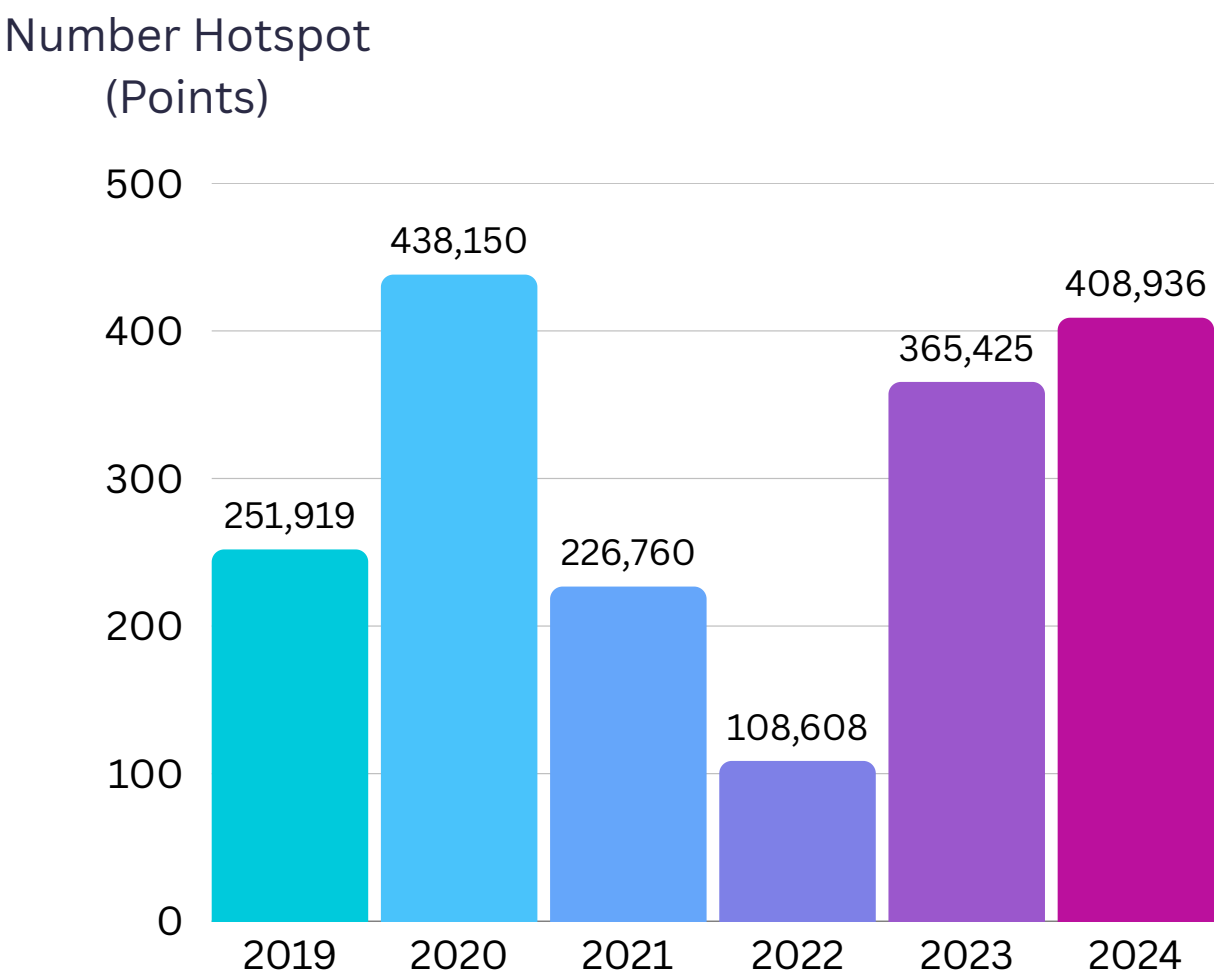
Monthly PM2.5 levels and trends in 2000 to 2024 (25 Years)



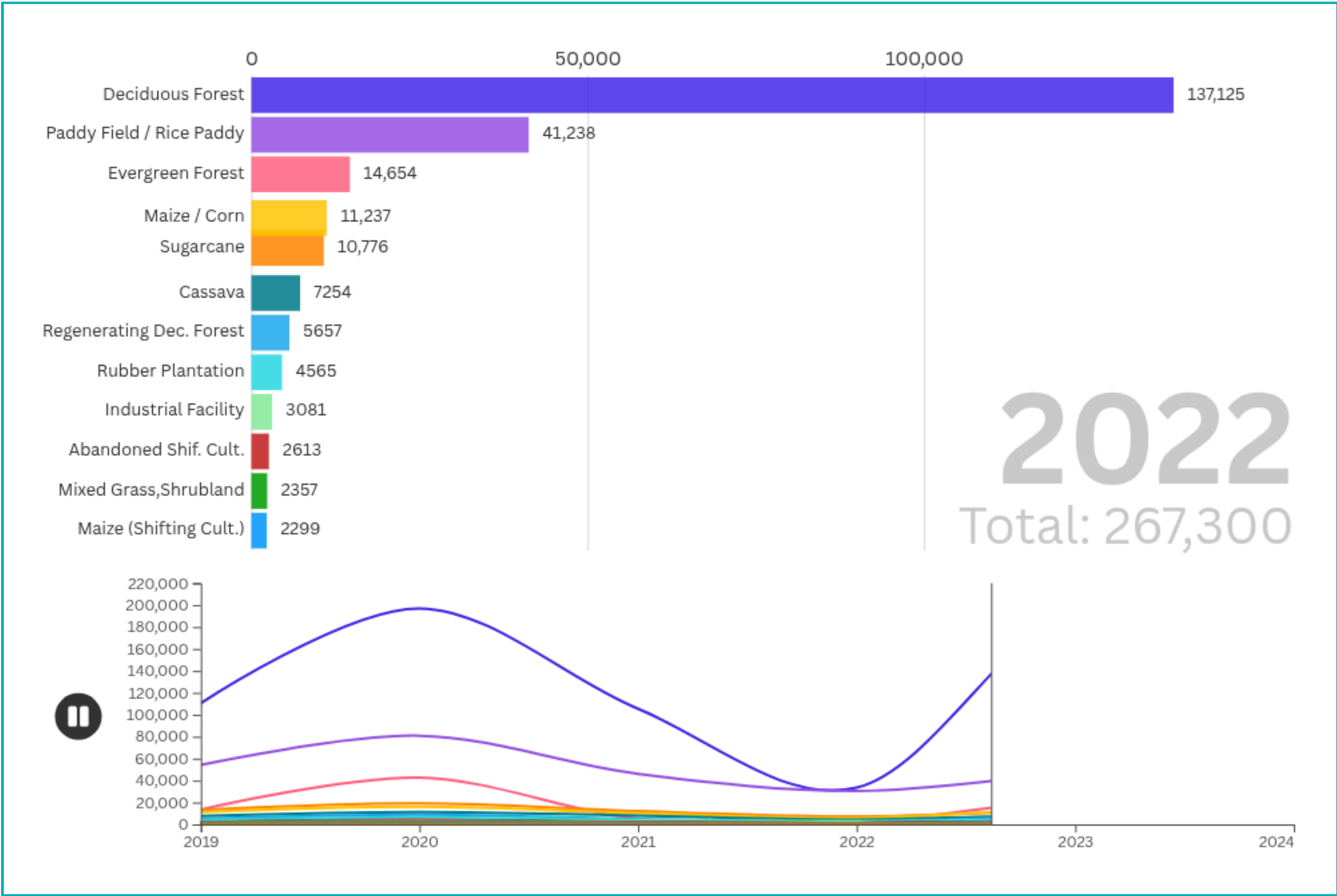
March, April, May, and October



Fire Hotspot Situation in Thailand (2019-2024)

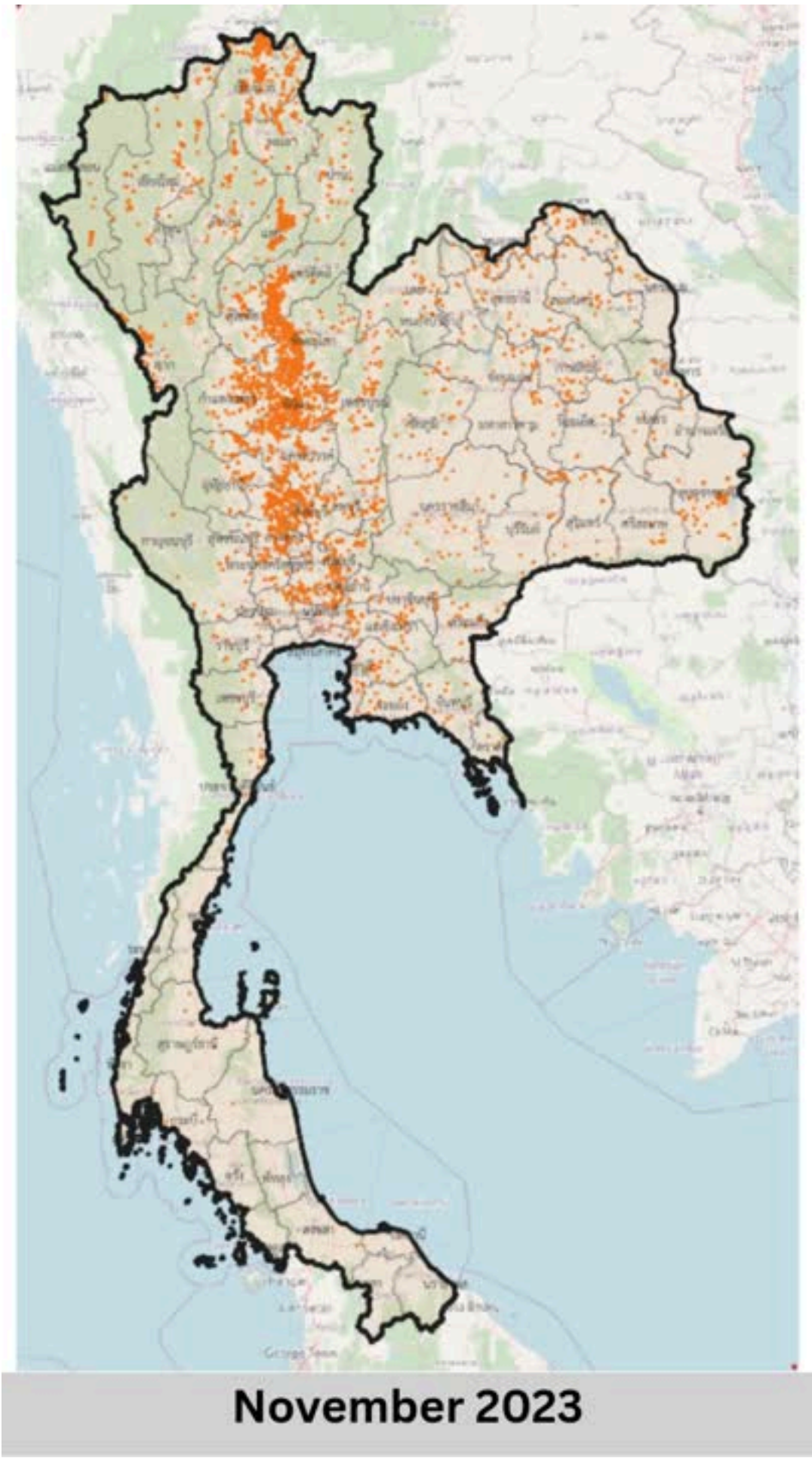
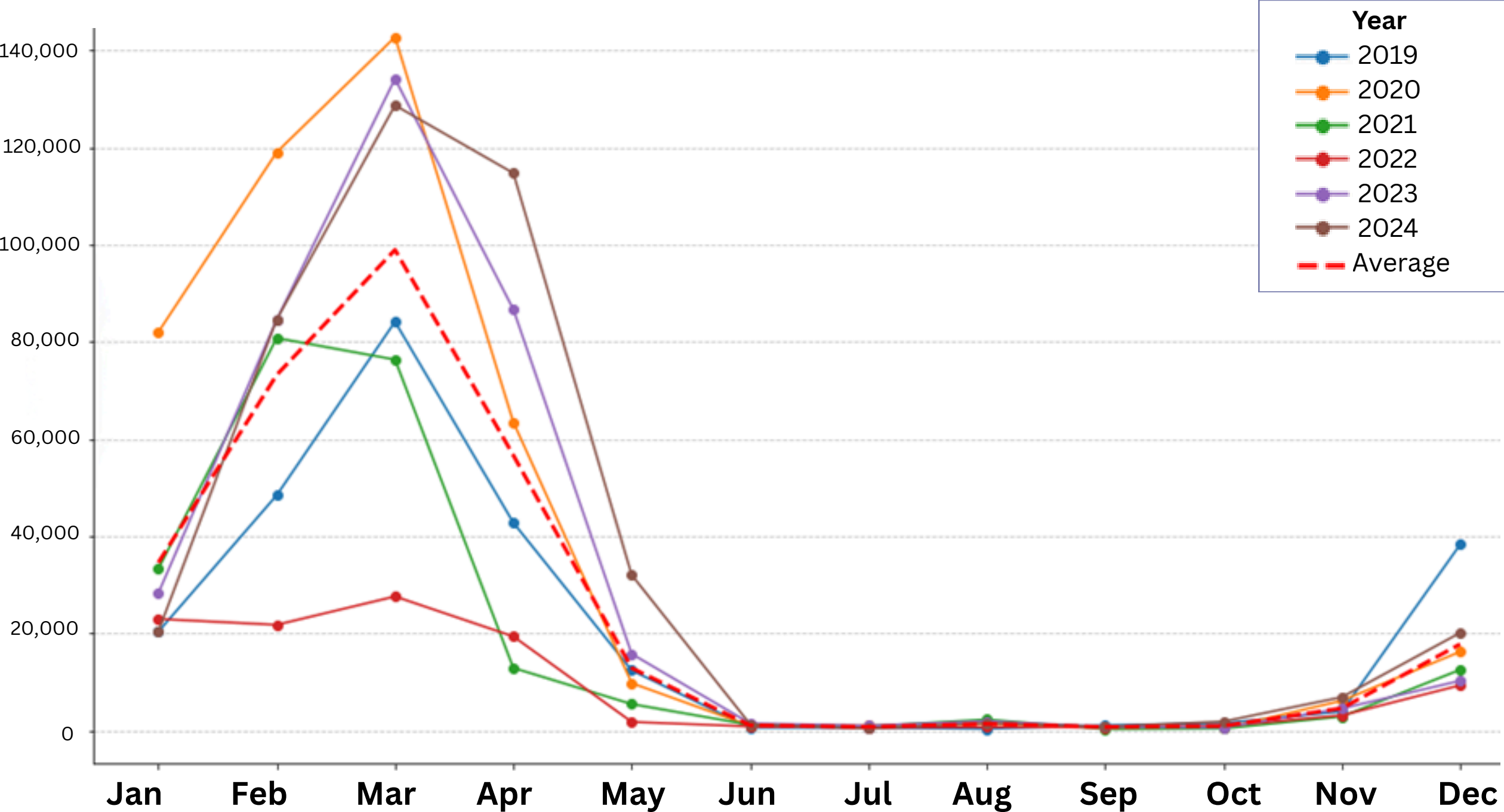


Hotspot Distribution across Land Use Categories



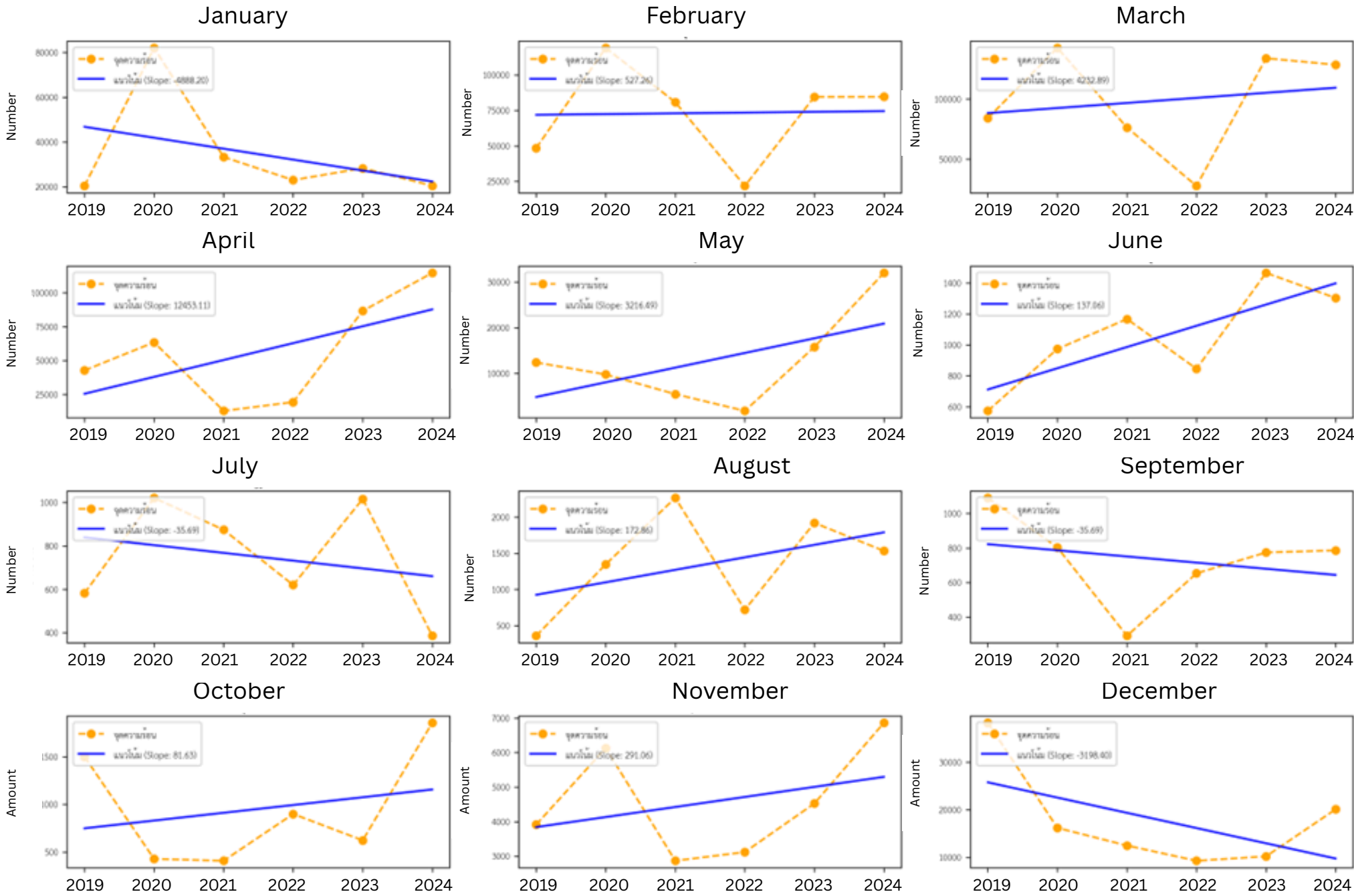
Fire Hotspot Situation in Thailand (2019-2024)

Monthly Fire Hotspot Situation in Thailand (2019-2024)

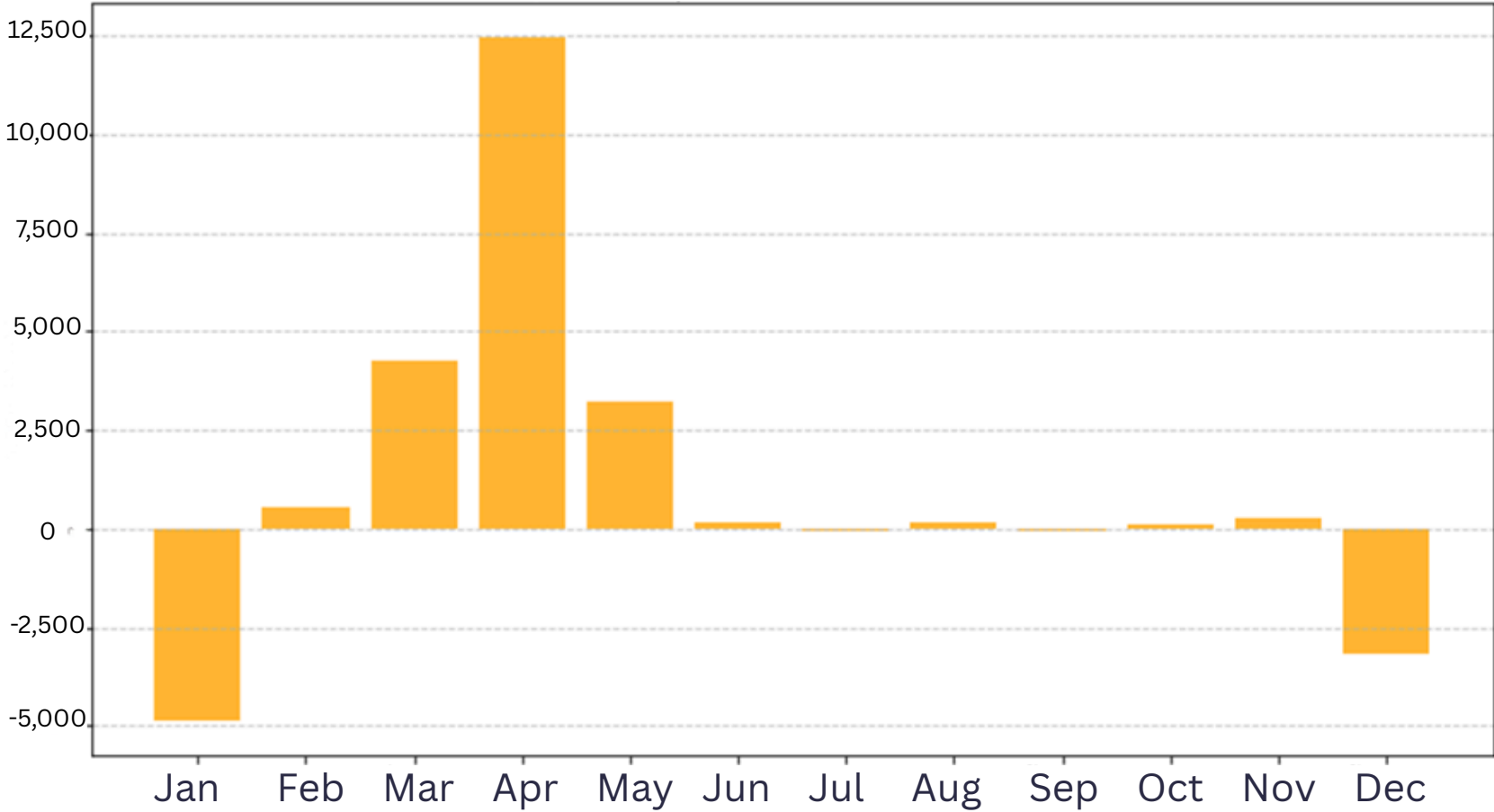


Fire Hotspot Situation in Thailand (2019-2024) ●●●

Monthly Fire Hotspot and Trend Changes from 2019 to 2024

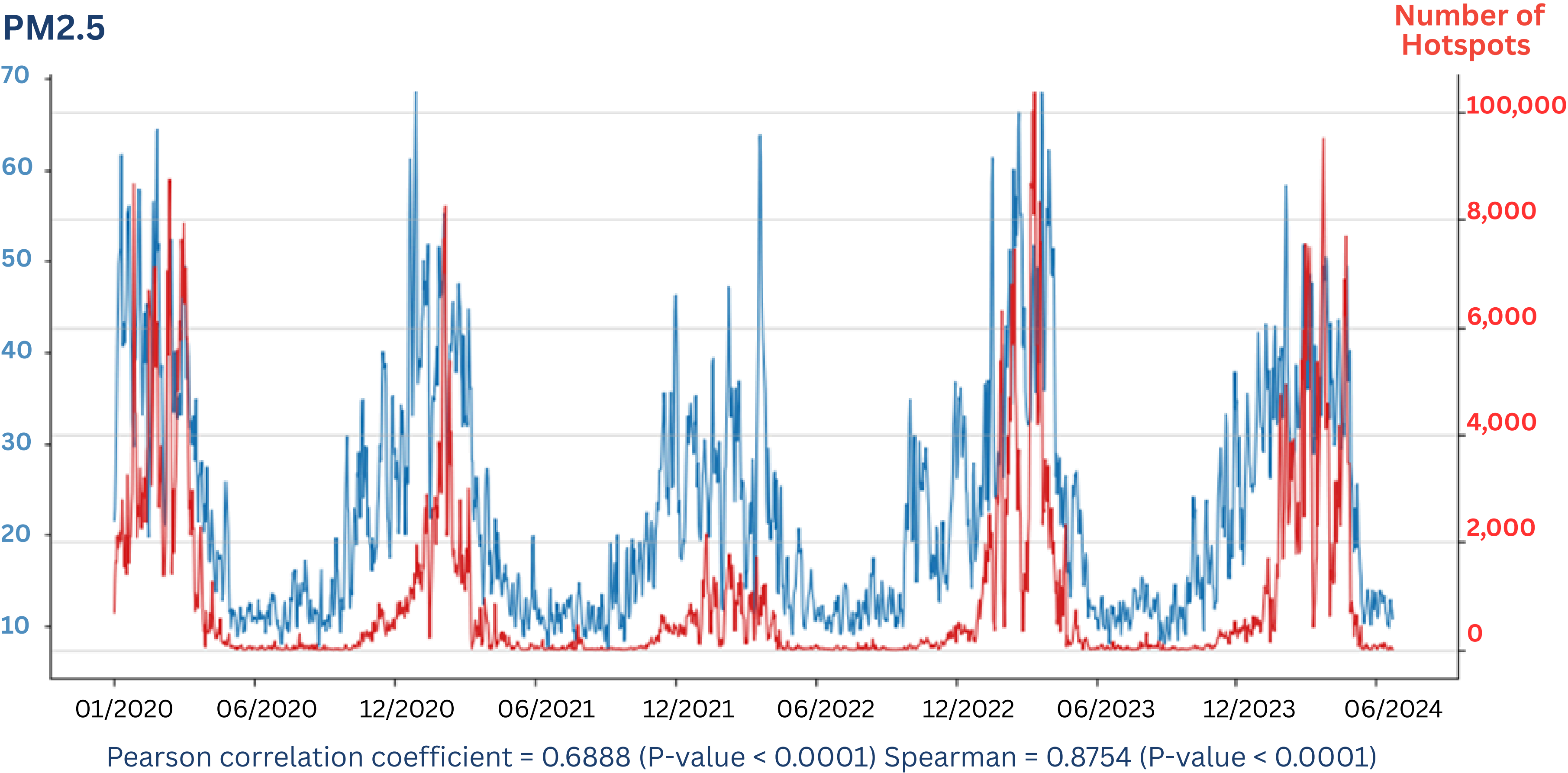


Monthly Fire Hotspot trend (Slope)



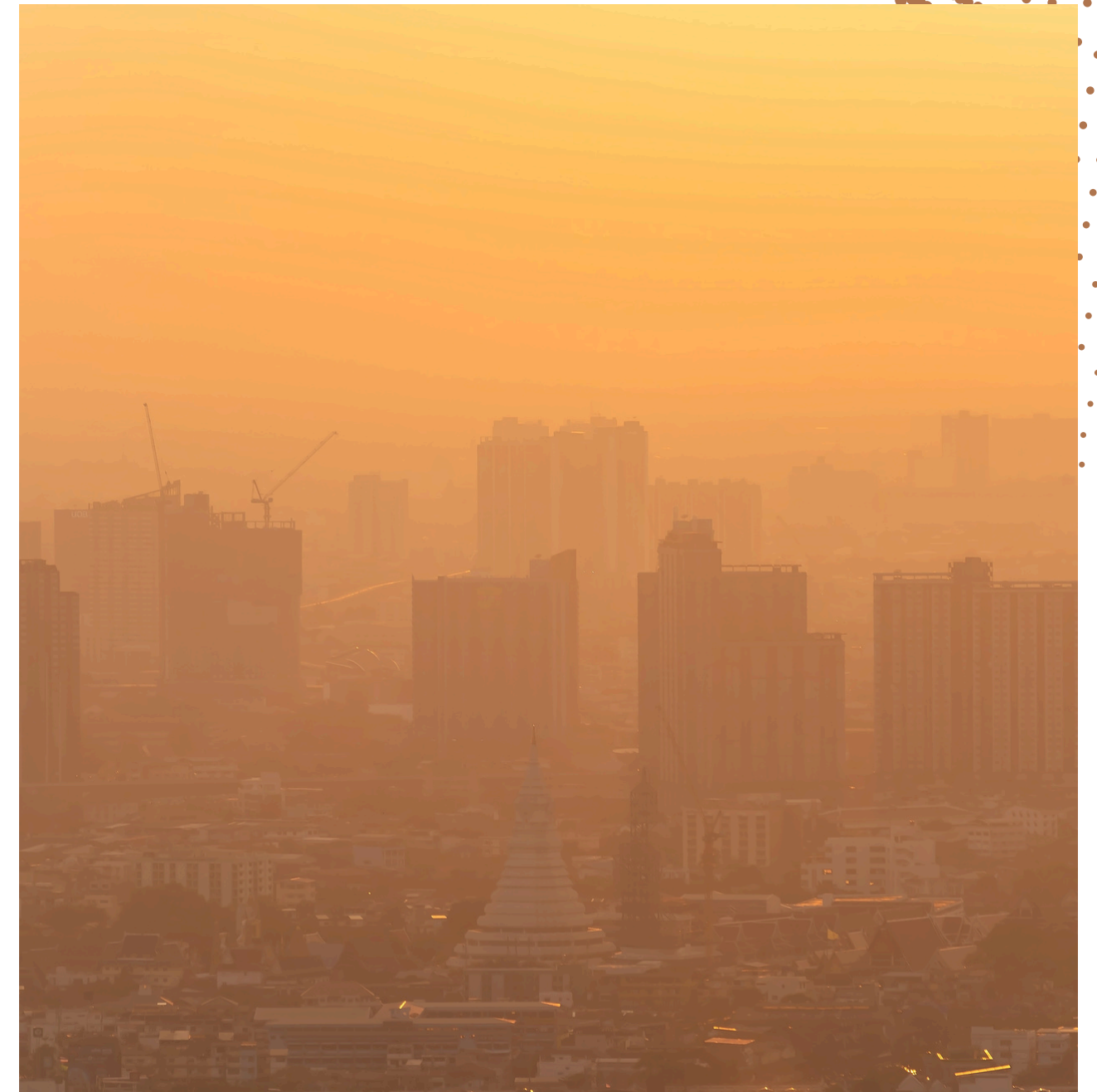
April, March, May, and February

The Relationship Between Hotspots and PM 2.5 (2020–2024)



Overview Key Findings

The government's actions to mitigate PM2.5 pollution have shown limited effectiveness. In other words, the measures implemented so far have proven insufficient to resolve the issue.



●●● Focus on: Preventing and reducing Open Burning in Sugarcane Cultivation Areas



Burnt Sugarcane

Target



10%

5%

0%

2021/2022

2022/2023

2023/2024

■ Key Measures Implemented

✓ Financial Support for Fresh-Cut Sugarcane

- 2019/2020 : 92 baht/ton
- 2020/2021 - 2022/2023: 120 baht/ton

✓ Penalty Deduction for Burnt Cane

- 30 baht/ton

✓ Interest Subsidy for buying harvesters

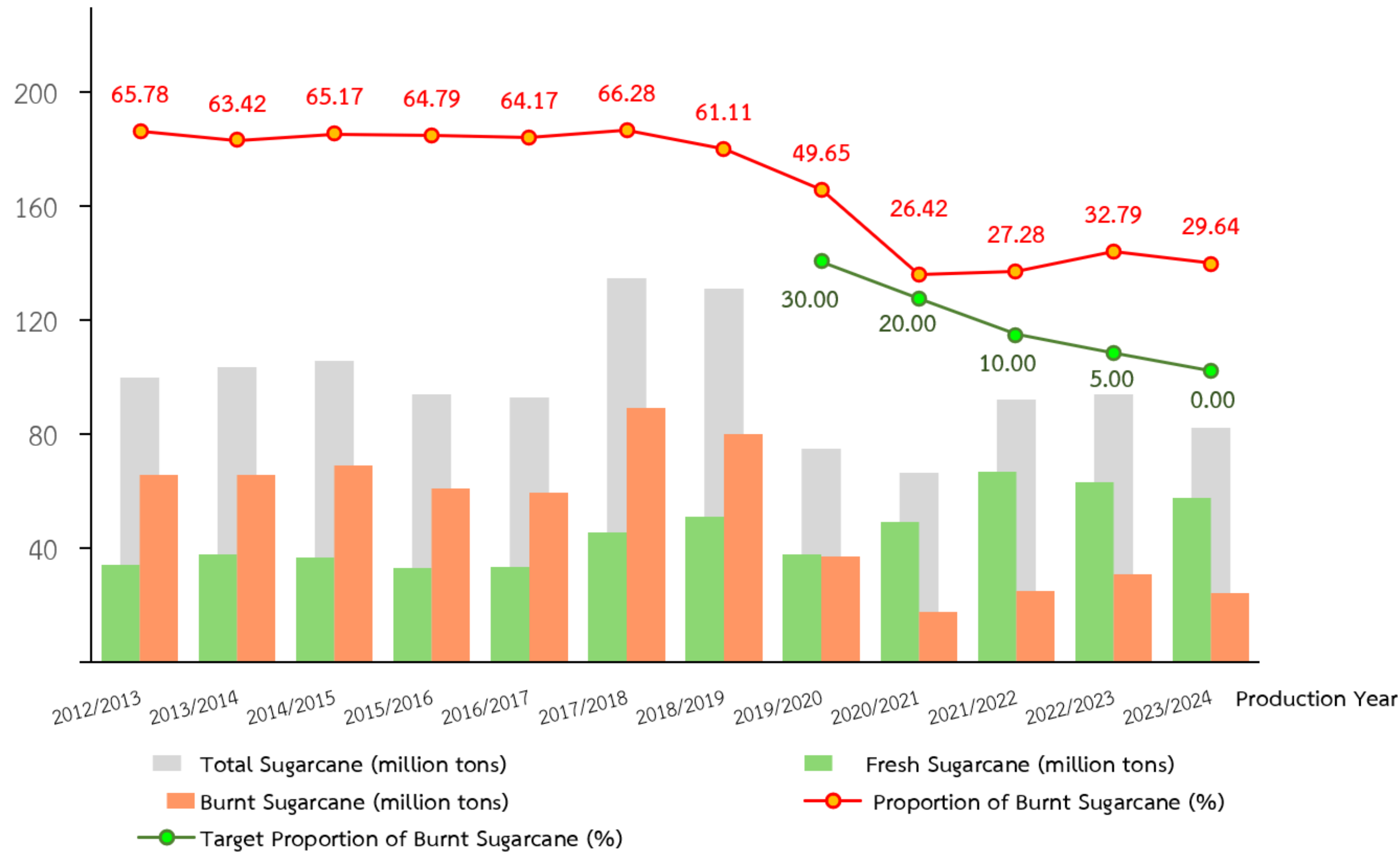
✓ Collaboration request to sugar factory

✓ Lend leaf-stripping machines

Sugarcane Delivery to Mills by Farmers

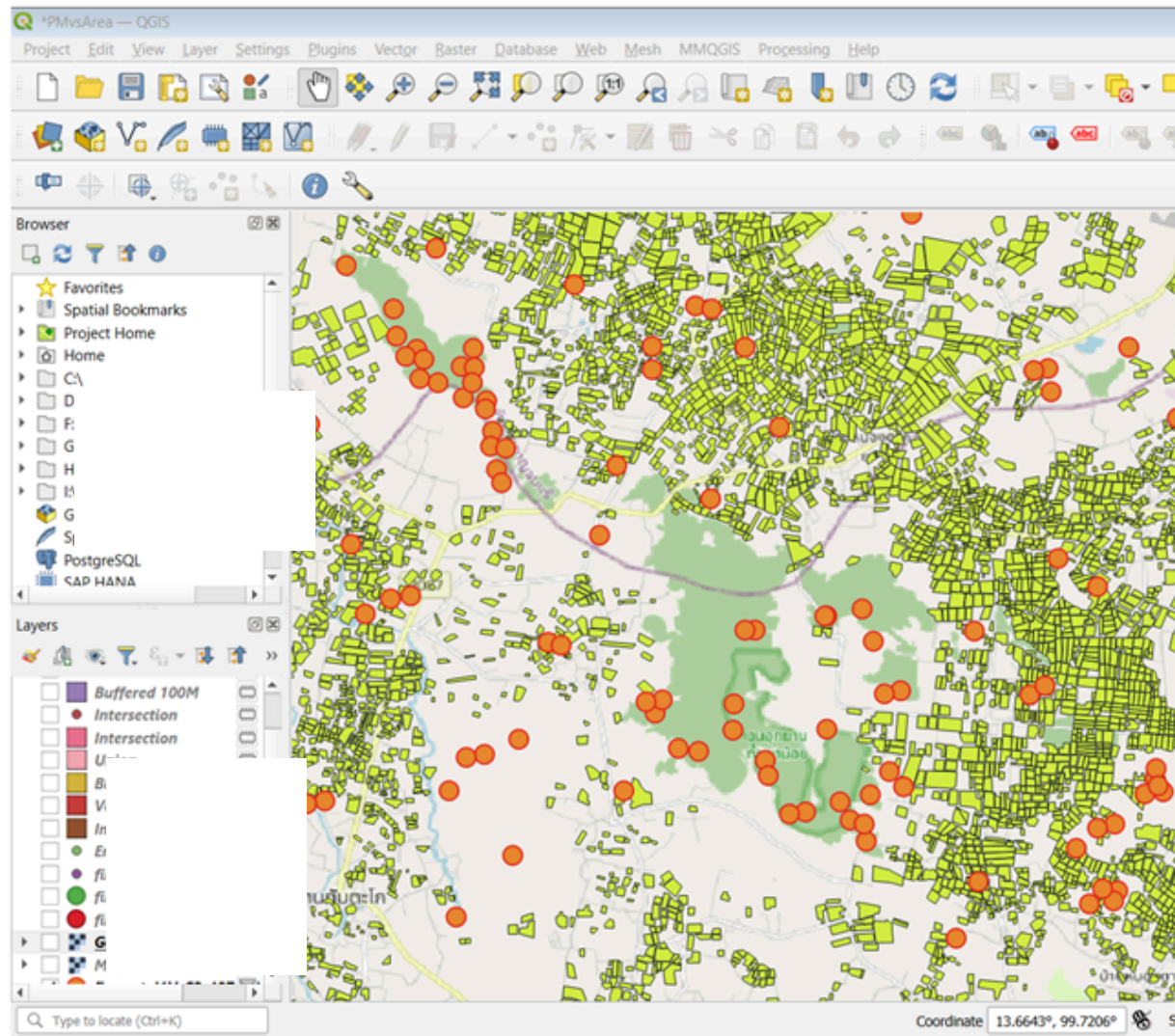


Sugarcane Volume (million tons)

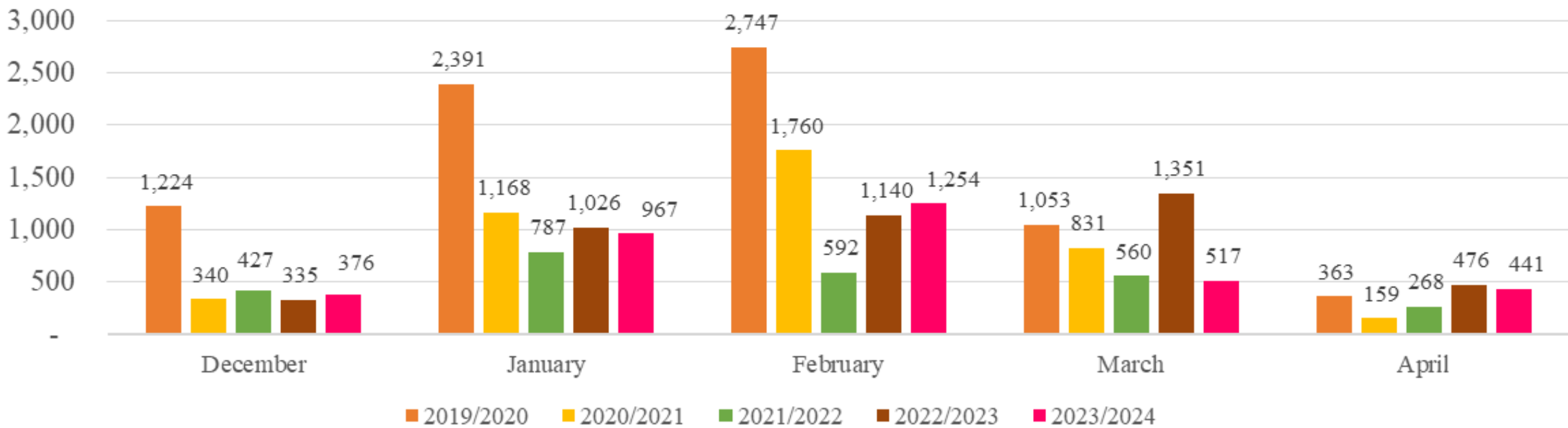


Proportion of burnt sugarcane has exceeded the target in **every** production year.

Open Burning and Hotspot in Sugarcane Cultivation Areas

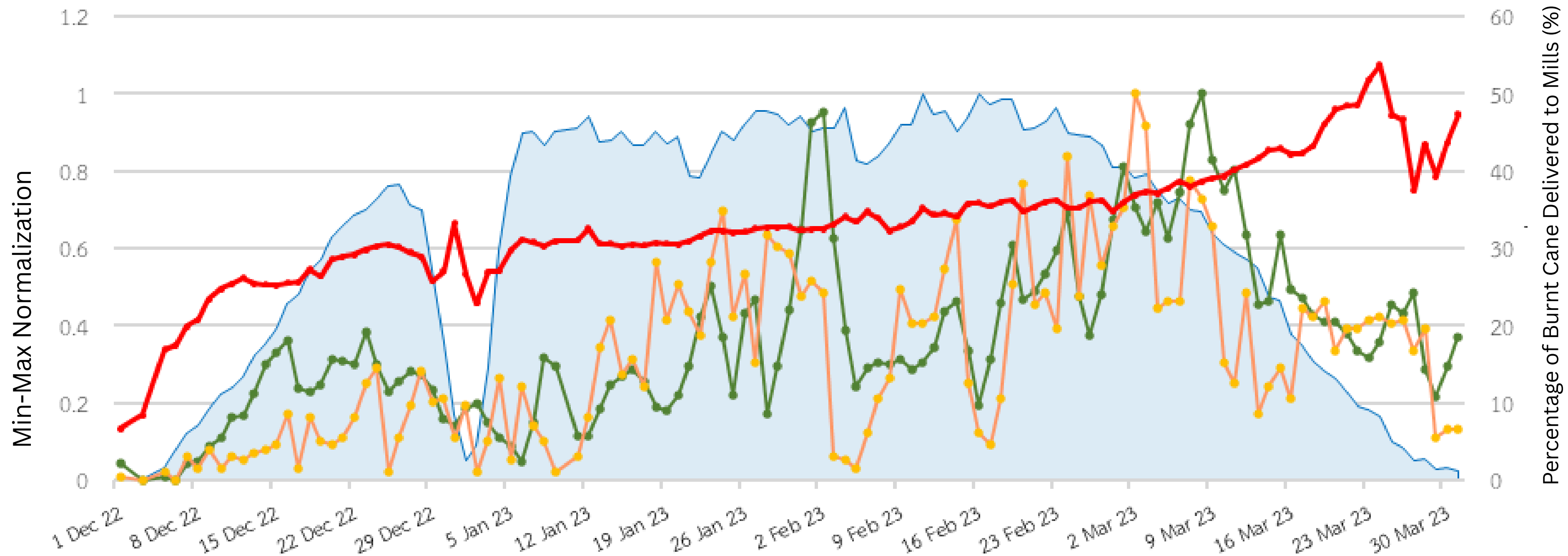


Number of Hotspots (points)





Daily Burnt Cane, Hotspots, Burnt Ratio, and PM2.5 – 2022/2023



Pearson Correlation Coefficient

- PM2.5 $\leftrightarrow$ Number of hotspots: $r = 0.634$
- PM2.5 $\leftrightarrow$ Percentage of burnt cane: $r = 0.519$
- Number of hotspots $\leftrightarrow$ Percentage of burnt cane: $r = 0.441$

Government Measures to Promote Fresh-Cut Sugarcane

in the following crop year

Cash subsidy (direct payment)

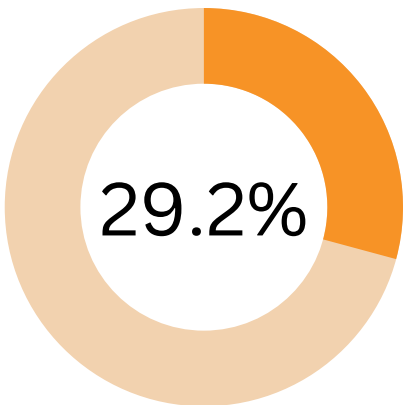
Crop 2021/2022



8,110.96 million baht 114,890 farmers



farmers delivered
more burnt cane



Low-interest loans for farmers

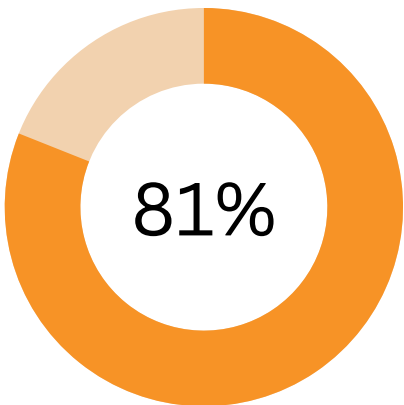
Year 2018–2023



580 farmers

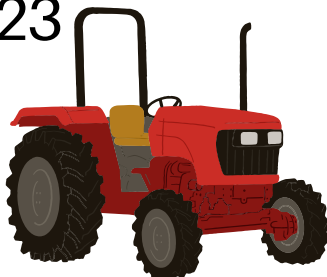


farmers delivered
burnt cane



Leaf-stripping machines provided for use/loan

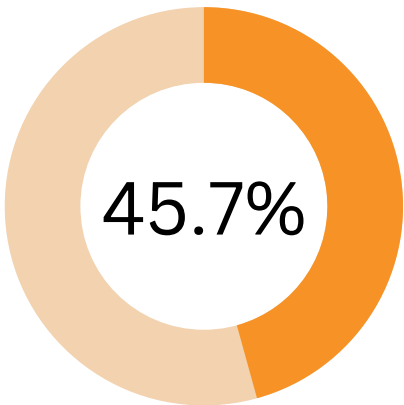
Crop 2022/2023



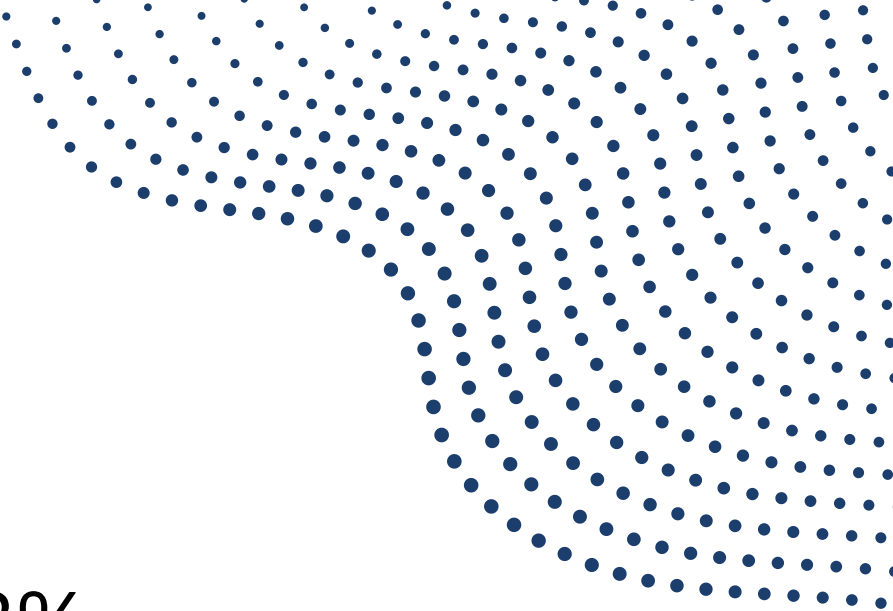
256 farmers



farmers delivered
more burnt cane



Burnt Cane Penalty and Farmer Behavior



✓ 2022/2023

Number of farmers
penalized



56,343 farmers



farmers delivered
more burnt cane

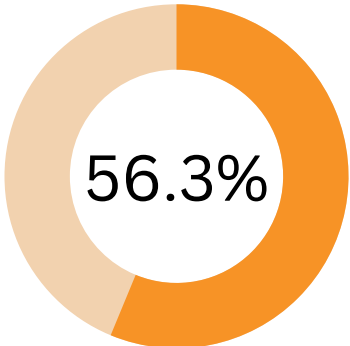


32.3%

Leaf Cane and residue management Post-harvest

From field surveys

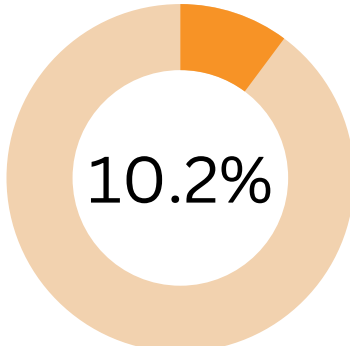
• Fresh cane harvesting



56.3%

Post-harvest burning

• Pre-harvest burning

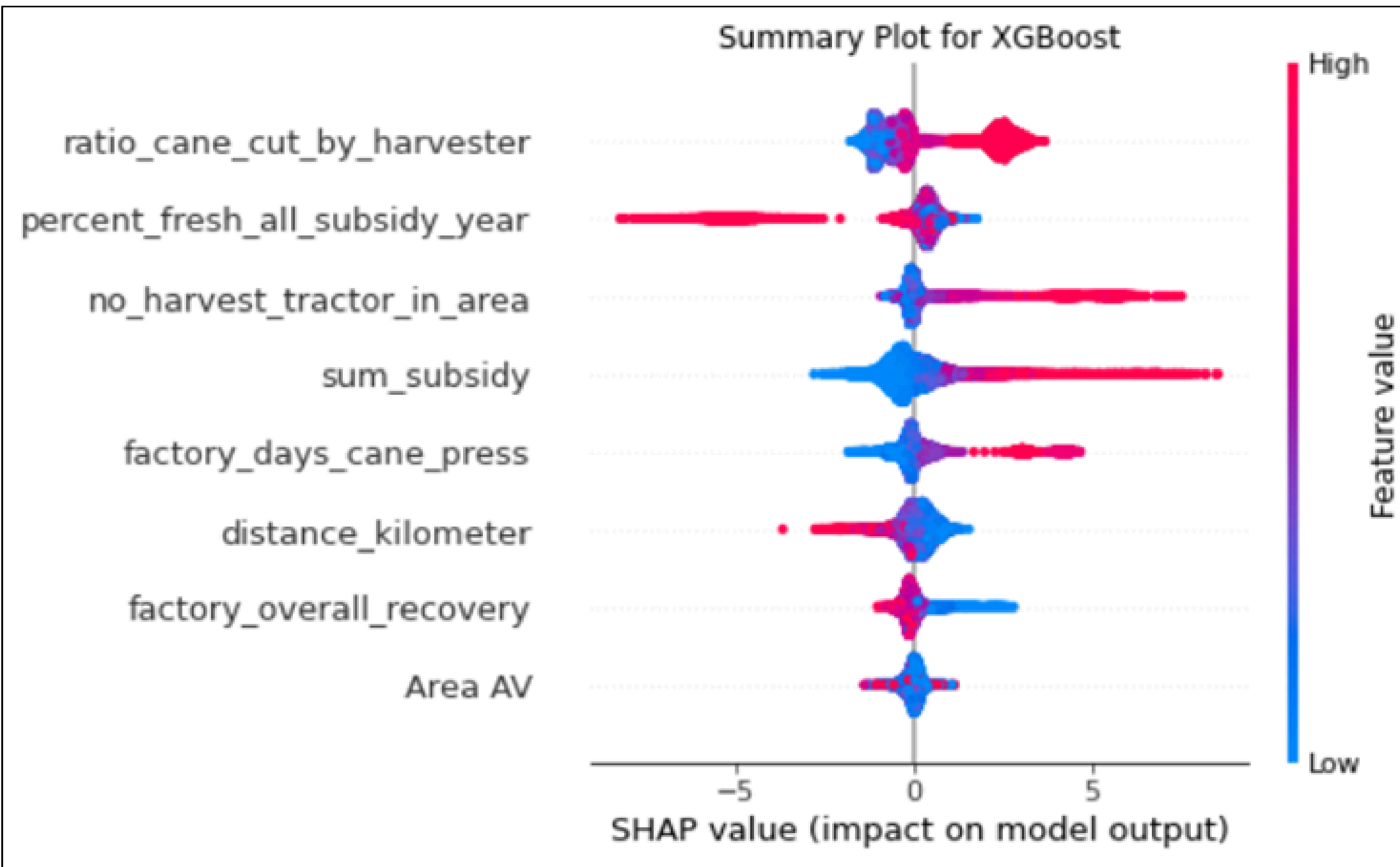


10.2%



Key Factors Influencing the Success in Reducing PM2.5 in Sugarcane Areas

The XGBoost model achieved the highest predictive performance, with Accuracy of 0.8242



Feature importance analysis

- Number of sugarcane harvesters available in the area
- Proportion of fresh cane harvested by machine (%)
- Period of cane-receiving at sugar mills



Policy Recommendations

- Expand Scope Beyond Sugarcane
 - Include other major agricultural sectors (e.g., rice, maize, cassava) under the anti-burning initiatives.
 - Burning in natural forests and newly reforested zones
- Shift from direct subsidy only toward area-based problem solving, like land issues or lack of machines
- Increase penalties for burnt sugarcane
- Enforce stricter sugar mill policies against accepting burnt cane.
- Support using machines for fresh cane cutting
 - Make fields suitable for machine use
 - Offer incentives to entrepreneurs and factory investing in machine harvesting.
 - Government, farmers, and sugar mills should plan together for planting and harvesting.



BENEFITS

Applying Big Data Analytics in Auditing

✓ Enhance Accuracy and Precision

- Analyze large datasets to reduce errors from traditional sampling methods
- Use in-depth data analysis to spot hidden patterns and to discover trend

⚙ Improve Operational Efficiency

- Reduce the time to process and analyze data
- Use visual tools to help teams clearly understand and communicate findings.



Recommended next steps

- Strengthen data analytics capacity for auditors at all levels—through hands-on training, role-specific upskilling, and real-case practice.
- Promote a data-driven audit culture that enables deeper analysis and evidence-based conclusions.
- Develop a Modern Audit System with integrated tools and a Data Lab that connects to external agency databases.
- Provide structured support through Data Support Teams and Data Analysts who assist auditors throughout the audit process.



**THANK YOU
VERY MUCH**

