Mitigation of Particulate Matter Problems Caused by Vegetation Fires in Thailand

UNIVERSITY OF Southampton

Sirirat Yensong, Ian D. Williams, and John Preston

1. Introduction

Vegetation fires are the main source of atmospheric pollutants in the north of Thailand. Every year in the so-called "fire season" from February to April, PM_{10} (particulate matter with an aerodynamic diameter ≤10 μm) concentrations in the atmosphere have increased and have been higher than the daily national ambient standard for Thailand of 120 μg/m³. This affects people's health in terms of respiratory illnesses and premature deaths and necessitates the management of fire by the Government.

The major causes of fires in Thailand are local people using fire to collect forest products and operating agricultural areas. To mitigate the PM_{10} problem so as to achieve the daily Thai air quality standards, the size and location of forest and agricultural areas for fire controlled in the fire season were estimated by a mathematical model.

2. Methodology

The study period 26 February to 1 March 2012 was used for a simulation using an air quality model. The PM_{10} loadings from each land-use type of vegetation fire source were estimated by the numbers of hotspots derived from satellite fire-active products with Moderate Resolution Imaging Spectroradiometer (MODIS) (see Figure 1). The emissions (E) of each vegetative type were estimated using the equation from Seiler and Crutzen (1980).

$$E = A \times FL \times CC \times EF$$

Where A denotes the burned area (m²), FL is the fuel load or biomass density (kg Dry Matter m⁻²), CC is combustion completeness or burning efficiency (%), and EF is the specific emission factor (g/kg Dry Matter)

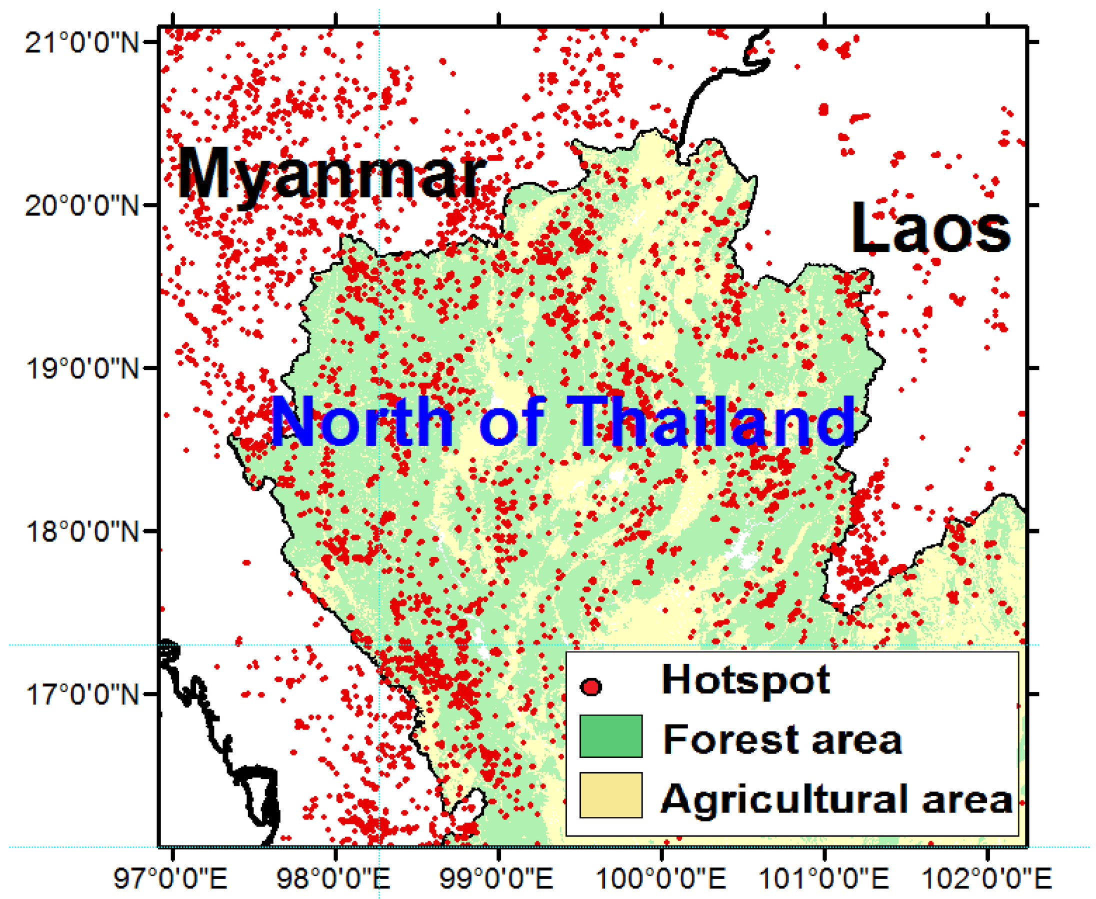

Figure 1.The location of hotspots in the forest and agricultural are in north of Thailand and neighbouring countries during 26 February and 1 March 2012

This study used a meteorological mesoscale model (MM5) to generate the metrological data needed to inform the air quality model. The input data for running MM5; terrain, land use and meteorology, were taken from the National Center for Atmospheric Research (NCAR). CALifornia PUFF (CALPUFF) was used to simulate reductions in PM_{10} concentrations so as to meet Thai air quality standard. The land-use types of fire sources were classified for finding the main source of the smoke problem including neighbouring countries, village, agricultural and forest areas. The scenarios for solving problems were set as follows:

- Simulation of PM_{10} concentrations after setting no fire areas in agricultural areas and forest areas (within a range of 1 km of agricultural areas)
- Simulation of PM_{10} concentrations after setting no fire areas in agricultural areas and forest areas (within a range of 1 km of agricultural areas), and neighbouring countries
- Simulation of PM_{10} concentrations after setting no fire areas in agricultural areas and the surrounding 4 km exclusion zone

3. Meteorology Results

In the north of Thailand, the terrain elevation is more than 300 m above sea level. There are a number of valleys formed by mountains which run parallel from north to south direction (see Figure 2)

The wind directions from the MM5 was analysed by the PRTMET program and plotted by the ArcMap program. The most common wind directions in the north of Thailand during 26 February and 1 March 2012 were the south and the southwest directions. An example of the result in 28 February 2012 is shown in Figure 3.

The average mixing heights of these areas were less than 500 m (see Figure 4) which were low mixing heights. This meteorology tends to be stagnant weather.

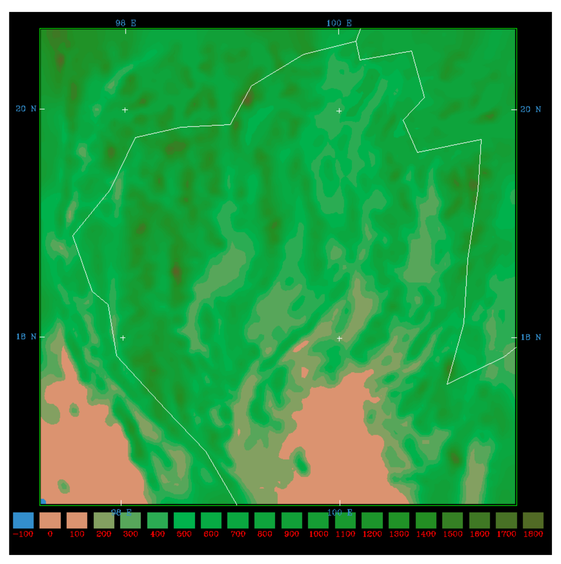

Figure 2. The terrain elevations of the north of Thailand area

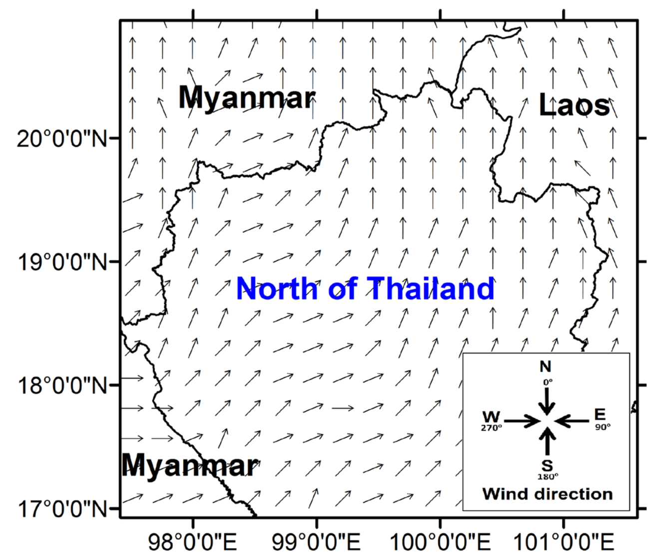

Figure 3. Results of simulated wind direction by the MM5 model in 28 February 2012

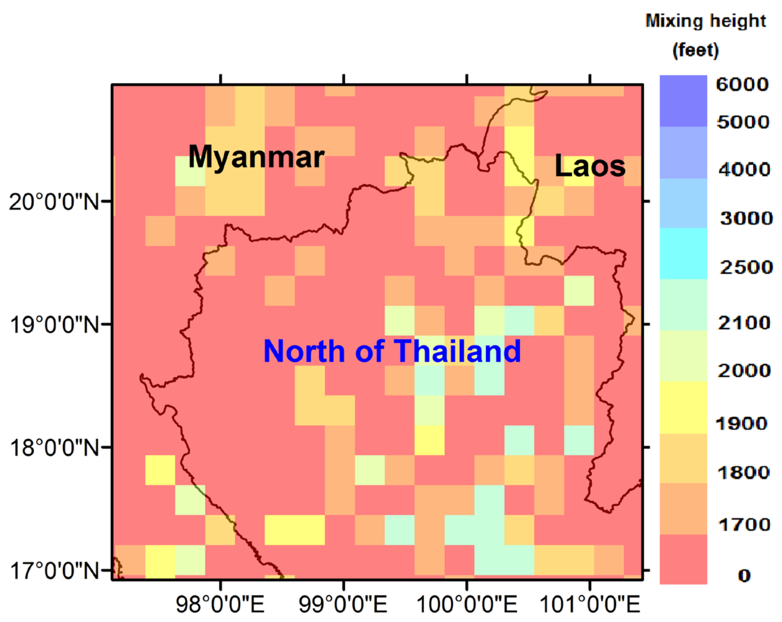

Figure 4. Simulation results of averaged mixing height during 26 February to 1 March 2012 by the MM5 model

4. Air Quality Results

Vegetation fires heavily affected air quality by increasing PM_{10} concentrations across the study area by more than 50 μg/m³ (see Figure 5).

After fires were controlled in agricultural areas and forest areas (within a range of 1 km of agricultural areas), PM_{10} concentrations were significantly decreased in many areas as shown in Figure 6.

However, PM_{10} from neighbouring countries was less affected because the inner areas of the north of Thailand still have the PM_{10} problems (see Figure 7) same as the condition in Figure 6.

Results show that after fires were controlled in agricultural areas and the surrounding 4 km exclusion zone in Thailand, most areas have PM_{10} concentrations no more than 120 μg/m³ except areas close to neighbouring countries (see Figure 8).

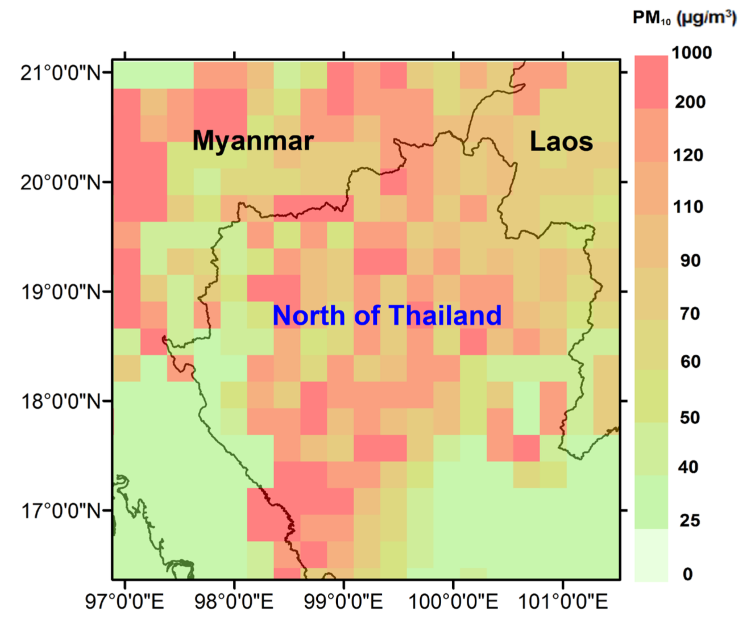

Figure 5. Results of simulated PM_{10} concentrations caused by vegetation fires in 28 February 2012 (before fires controlled)

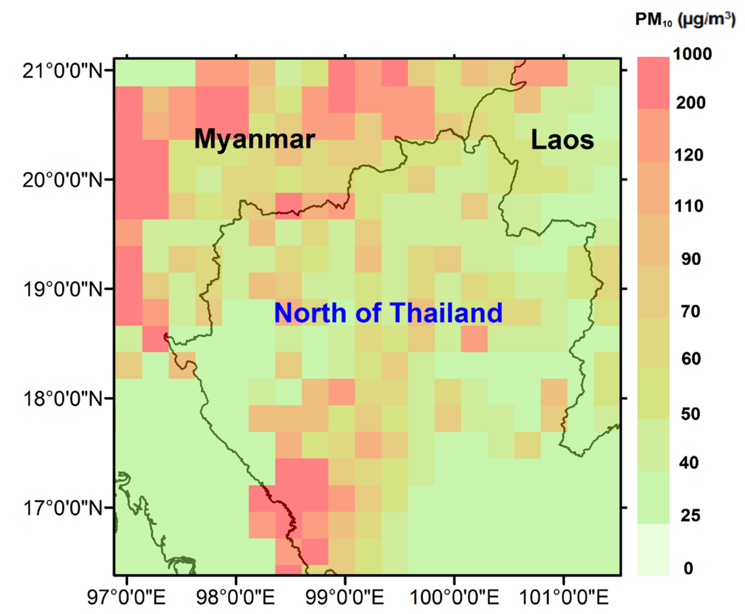

Figure 6. Results of simulated PM_{10} concentrations after fires controlled in agricultural areas and forest areas within a range of 1 km of agricultural areas in 28 February 2012

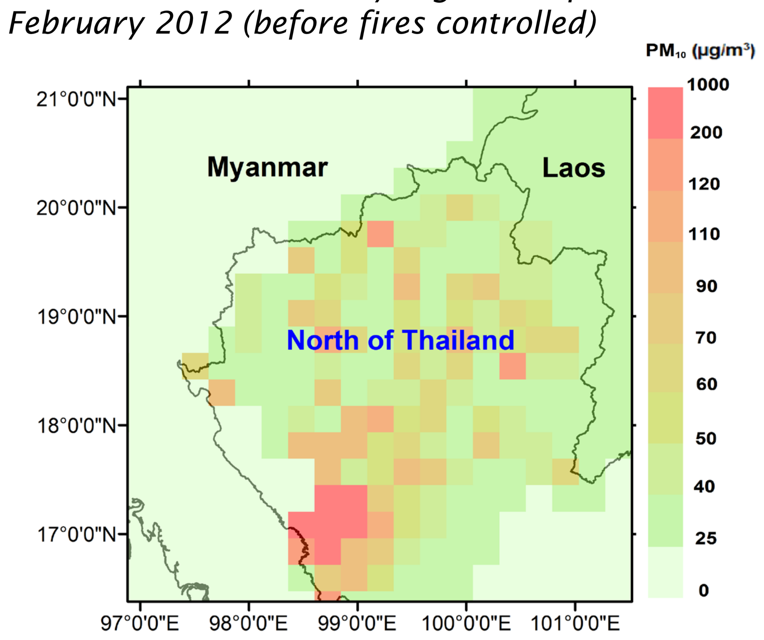

Figure 7. Results of simulated PM_{10} concentrations after fires controlled in neighbouring countries, agricultural areas and forest areas within a range of 1 kilometres of agricultural areas in 28 February 2012

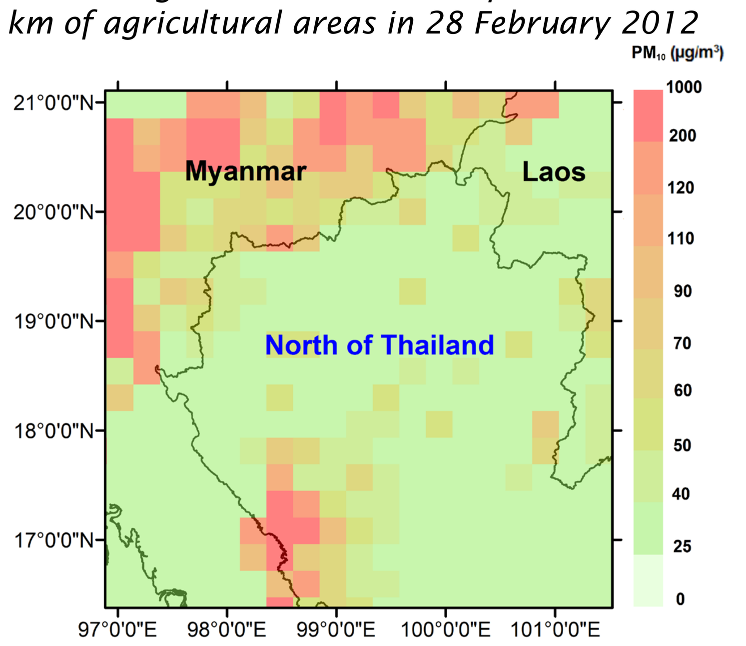

Figure 8. Results of simulated PM_{10} concentrations after fires controlled in agricultural areas and forest areas within a range of 1 km of agricultural areas in 28 February 2012

5. Conclusions

Most vegetation fires were on the borders of agricultural and forest areas (Figure 1) and occurred within a range of 1-4 km of villages and agricultural areas. This area is a major cause of fires and a focal point for government action.

PM_{10} from nearby countries was less affected than the local PM_{10} because wind directions were southerly and south-westerly and originated over the ocean. Fires controlled in agricultural areas and the surrounding 4 km exclusion zone in Thailand eradicated most areas from having PM_{10} concentrations greater than 120 μg/m³ except areas close to neighbouring countries.

The meteorology as a mixing height is an important factor for the smoke problem in this study area. A few hot spots in the area can cause high concentrations of PM_{10}. High mixing heights are good for the dispersion of pollutants whereas low mixing heights tend to be stagnant and pollutants are usually trapped near the ground (Hardy et al., 2001).The mixing height, which may lead to a smoke problem near the ground is less than 1,700 feet or 500 meters (NWS and NOAA, 2015). With this weather condition, the prescribed burning (or controlled burning) are not allowed in many states in the United States. Results from models showed that the most of the study area had the averaged values of mixing height during 26 February to 1 March 2012 of less than 1,700 feet .

6. References

DEPARTMENT OF NATIONAL PARKS WILDLIFE AND PLANT CONSERVATION 2012. Anual Report 2012 of Forest Fire Control Division (in Thai).

HARDY, C. C., OTTMAR, R. D., PETERSON, J. L., CORE, J. E. & SEAMON, P. 2001. SMOKE MANAGEMENT GUIDE FOR PRESCRIBED AND WILDLAND FIRE 2001 Edition National Wildfire Coordinating Group, Fire Use Working Team.

NWS & NOAA 2015. 2015 Fire Weather Operating Plan for Kentucky, Parts of Southern Illinois, and Southeast Missouri. National Weather Service and NOAA National Weather Service Forecast Offices

SEILER, W. & CRUTZEN, P. 1980. Estimates of gross and net fluxes of carbon between the biosphere and the atmosphere from biomass burning. Climatic Change, 2, 207-247.

Faculty of Engineering and Environment
University of Southampton,
Southampton, United Kingdom

Author contact details
Email:sy5e12@soton.ac.uk

Acknowledgement
Funding is provided by the Royal Thai Government