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2019 Emission Inventory Development in the Northern Part of Thailand

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Abstract

To address the issue of air pollution, local governments and responsible agencies must have reliable and accessible data on air quality. It is, however, extremely difficult to develop an effective mitigation strategy and policy in the absence of up-to-date emission inventory data. The goal of this research is to create an updated emission inventory in Thailand's northern region by using secondary data and a top-down approach for calculations. A GIS technique would be used to create not only an emission inventory, but also temporal and spatial distribution patterns of emissions, as well as gridded map. This study used UNEP's emission inventory manual method to estimate emissions in each source of pollutants, while applying the experiment established by the other project on estimating emissions from forest fires in Thailand using MODIS active fire product and country specific, in obtaining the average burn area in a forest fire event. The pollutants investigated in the study include sulfur dioxide (SO_2), nitrogen dioxide (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), ammonia (NH_3), methane (CH_4), black carbon (BC), organic carbon (OC), nitrous oxide (N_2O), coarse particulate matter (PM_{10}), and fine particulate matter ($PM_{2.5}$) in the northern part of Thailand. The result illustrated that these pollutants were emitted into the atmosphere about 10,179.34, 957.53, 1,910.08, 250.87, 39.27, 103.71, 13.07, 95.13, 0.38, 157.59, and 140.07 Gigagram per year, respectively. Most of emission was in Amphoe Muang, Chiang Mai province. It was approximately 300 - 400 tons per grid per year due to high density of population and road network. While Mae-Moh power plant was the main polluted in energy sector.

Keywords: Air pollution; Emission Inventory; Forest fire; Open burning; Northern part of Thailand; Hotspot

1. Introduction

Numerous countries have struggled with air pollution during the last few decades. One of the most serious contaminants is particulate matter with a diameter of equal to or less than 2.5 micrometers ($PM_{2.5}$). Numerous studies have been conducted on the health impacts of $PM_{2.5}$ (Bae & Hong, 2018; Feng *et al.,* 2016; Janssen *et al.,* 2013; J.-Z. Wu *et al.,* 2018).

Thailand was named the 23rd most polluted countries in the world in 2018, according to the World Air Quality Report (IQAir AirVisual, 2018). In 2018, the annual average concentration of fine particulate matter was 26.4 ug/m³. Each year, the northern part of Thailand has elevated air pollution especially PM concentrations from the open burning and traffic sources. As a result of the unfavorable meteorology, which includes a low mixing height and a calmbreeze, this pollutant tends to accumulate at low altitude, resulting in increasing pollutant concentrations throughout this period. the northern part of Thailand's pollution sources includes on-road and off-road transportation, open burning both agricultural and forest fire sector, industrial section, and residential sector (Pollution Control Department ; PCD, 2019).

In the northern part of Thailand, air pollution is the significance issue occurred every year especially particulate matter pollutants from open burning both agricultural and forest fire sector. Typically, the dry season between January and April is when air pollution problems are most severe. The agricultural sector is the primary source of pollution emissions. After the farmer harvests their crop, they must prepare the new area for the following year's agricultural production. Burning is a simple approach for dealing with agricultural residue that does not require a large investment. It may, however, contribute to an increase in the concentration of air pollution in the atmosphere. Chiang Mai has been one of Thailand's most polluted provinces during the last two years, with an air quality index of > 151.

This study aims to develop updated emission inventory in the northern part of Thailand covered 17 provinces using secondary data and top-down approach to identify the activity data for calculating. Not only develop emission inventory, but also develop the emission distribution map using GIS technique.

2. Materials and Methods

2.1 Scope of study

This study estimated the emission inventory including Sulfur dioxide (SO_2), Nitrogen dioxide (NO_x), Carbon monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOC), Ammonia (NH3), Methane (CH_4), Black Carbon (BC), Organic Carbon (OC), Nitrous oxide (N_2O), Coarse Particulate Matter (PM_{10}), and Fine Particulate Matter ($PM_{2.5}$) using secondary data in 2019. The study area covers the northern part of Thailand which includes 17 provinces (Chiang Mai, Chiang Rai, Mea Hong Son, Lamphun, Lampang, Phrae, Nan, Payao, Phitsanulok, Pichit, Phetchabun, Tak, Nakhon Sawan, Uttraradit, U-thaithani, Sukhothai, Kampheang Phet) as shown in figure 2.1

2.2 Data collection and preparation

To develop emission inventory, secondary activity data from the government and private sectors will be used in this study. These types of databases were systematically collected and reliable to reference in the future. The sources of pollutants were distinguished into five main groups, including household, industrial, agricultural, forest fire, transportations, and energy sectors.

Thailand's endues fuel and total energy consumption was derived from the Energy Policy and Planning Office (EPPO) and the Department of Alternative Energy Development and Efficiency (DEDE) for the year 2019. However, the information received is on a national scale. Thus, the provincial total fuel consumption in each type per capita would be defined using the National Statistical Office of Thailand (NSO) for the same year. Additionally, due to the distinctions in endues fuel types between urban and rural areas, the gridding population density from the United Nations would be used to classify based on the European commission's new degree of urbanization suggestion. Therefore, the grid cell with a population greater than 300 people/km^2 was chosen to identify an urban cluster. In comparison, the remaining grid cells with a population less than or equal to 300 people/km^2 are designated as rural areas.

The Department of Industrial Works (DIW) can provide information on the horsepower and the Number of factories in each industrial category in the northern part of Thailand for 2019. However, because this study focuses on calculating the emission inventory in the industrial sector, the power sector would be separated into another part.

The Regional Office of Agricultural Economics 1 can also provide annual crop yields for rice, soy, maize, cassava, potatoes, groundnut, and sugar cane. To spilt out the annual activity data to monthly, the cultivation calendar of each crop type would be used. For instance, rice harvesting in paddy fields and highland locations will begin in November and continue through April of next year. In practice, the farmer will burn the straw and crop residual waste during the drought

season, which lasts from October to April, with the peak occurring in February and March due to the dried biomass. Thus, the month of activity data in crop residual waste burning will be between October and April. However, this study focused on the local government's stop to burn policy. Therefore, monthly activity data will be prioritized following this policy.

In the forest fire sector, the hotspot data was obtained from MODIS Terra and Aqua satellite system, which has an orbit pass the study area two times per day at 10.00 – 12.00 hrs. And 13.00 – 15.00 hrs. It could be downloaded from Fire Information for Resource Management System (FIRMS) developed by NASA (https://firms.modaps.eosdis.nasa.gov/map/). Then, the sampling points were selected only the forest land area using the land use information provided by the land and development department.

2.3 Emission Inventory Development

To develop emission inventory in the 17 target provinces, we followed the method provided by UNEP's Atmospheric Brown Clouds – Emission Inventory Manual following standard estimation equation.

$$Ei = EF \times AR \times ((100 - CE)/100)$$

where,
Ei = Emission load,
EF = Emission factor
AR = Activity data
CE = Overall efficiency (%)

To investigate the emissions inventory of the road and transportation sector, activity data from each source would be gathered. The Department of Land Transportation (DLT) publishes an annual report that includes the registered vehicle number. The percentage of vehicles in use was calculated using data from the PCD's DIESEL project in 2004.). Additionally, the Number of LTOs could be determined by examining the Number of flights at each airport in the study area, as provided by the Department of Airports (DOA) and the Airport of Thailand (AOT).

In figure 2 represented the spatial distribution framework. An emission inventory was calculated for each section using the ABC guideline book and another reference. Finally, this section will utilize Geographic Information Systems (GIS) to create monthly and annual spatial distribution maps of emission inventories in the northern part of Thailand.

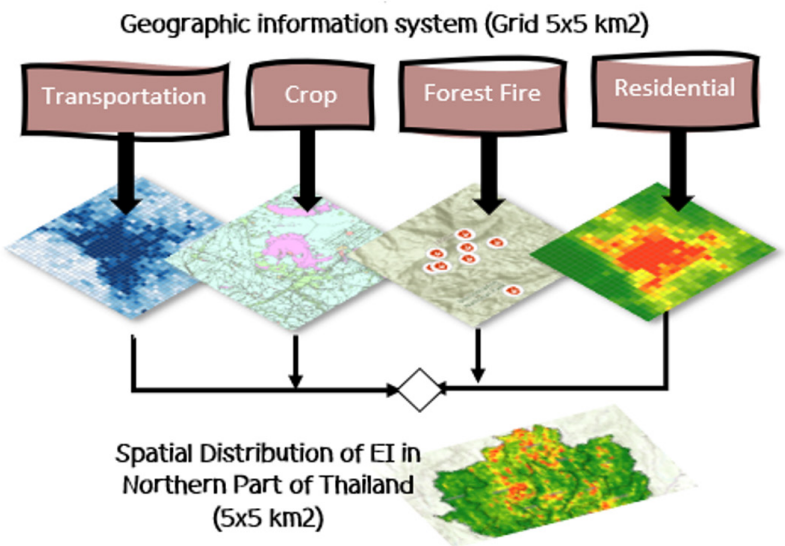

Figure 1. Spatial distribution framework

3. Results and Discussion

3.1 The Northern Part of Thailand Emission Inventory

As the result of the study, the northern part of Thailand emitted pollutants including Sulfur dioxide (SO_2), Nitrogen dioxide (NO_x), Carbon monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOC), Ammonia (NH_3), Methane (CH_4), Black Carbon (BC), Organic Carbon (OC), Nitrous oxide (N_2O), Coarse Particulate Matter (PM_{10}), and Fine Particulate Matter ($PM_{2.5}$) into the atmosphere about 10,179.34, 957.53, 1,910.08, 250.87, 39.27, 103.71, 13.07, 95.13, 0.38, 157.59, and 140.07 gigagram per year, respectively. Agricultural sector was the main polluter who emitted primary aerosol including fine and coarse particulate matter ($PM_{2.5}$ and PM_{10}) especially from the open burning activity. It is about 77% of the total emission, while industrial sector was the second polluter which emitted about 13 - 36%. The third one was on-road transportation sector.

Carbon Monoxide (CO) and Nitrogen Oxide (NO_x) were the major gas pollutants emitted in the study area. The findings indicate that crop production played a significant role in CO emission. It accounts for approximately 53% of total emissions. CO is a type of pollutant that results from an incomplete combustion process, which includes not only agricultural open burning but also the transportation sector. On the other hand, energy sector was the significance source of NOx emission. it accounts approximately 82% while transportation sector was 14 percentage in 2019. According to the DLT's 2019 annual report, over 5 million vehicles in Thailand continue to utilize the EURO 1 - 3 engine, with approximately 6% of vehicles in northern Thailand using the older engine. Although it is a small number, it emits approximately 200 times more emissions than newer technology vehicles such as EURO4-5. In addition, SO_2 emission was released from energy sector approximately 98%.

3.2 Emission Inventory in Each Sector in the Northern Part of Thailand

In 2019, on-road transportation sector released gas pollutants such as Sulfur dioxide (SO_2), Nitrogen dioxide (NO_x), Carbon monoxide (CO), Non- Methane Volatile Organic Compounds (NMVOC), Ammonia (NH_3), Methane (CH_4), Nitrous oxide (N_2O) into the atmosphere following 1.01, 134.46, 346.03, 38.85, 0.47, 12.89, 0.35 in unit of gigagram/year respectively while particle pollutant such as PM_{10} and $PM_{2.5}$ were emitted about 11.98 and 11.63 gigagram/year.

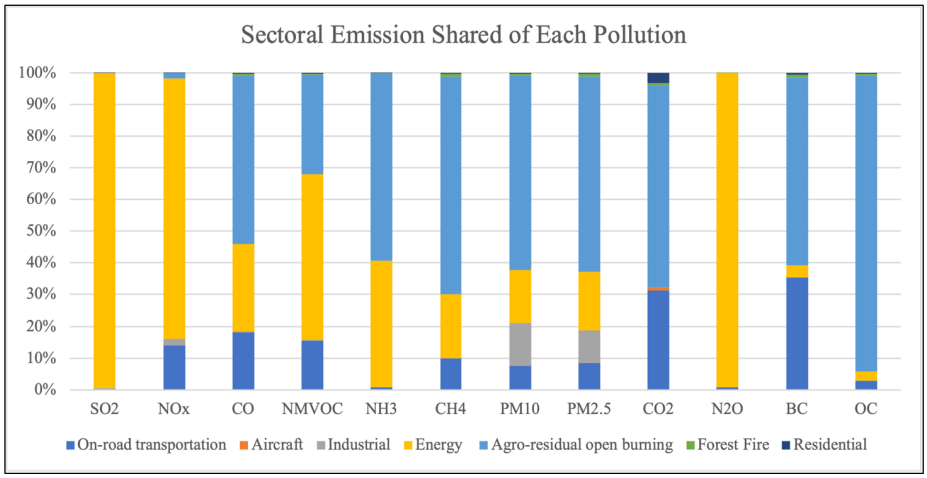

Figure 2. Share of emission percentage by source: on-road transportation, aircraft, industrial, energy, agriculture, forest fire and residential in the northern part of Thailand

In addition, the results of the emission inventory for the on-road segment revealed that carbon monoxide was the predominant pollutant generated by this source because of the incomplete combustion reaction in the engine chamber. The chief sources of these emissions were motorcycles and pickup vehicles.

Due to data constraints, the emission inventory for off-road transportation was limited to aircraft sources in this study. There are twelve airport which operate both international and domestic flight. The study's findings indicated that the most polluting substance emitted by this sector is carbon monoxide. Domestic flights (B737 - 400) released approximately 475.78 tons of CO into the atmosphere during the landing and takeoff phases per year, while international flights released approximately 123.41 tons per year. In term of NO_x emission, the total emission emitted into the atmosphere approximate 345.4 tones per year including 291.96 for domestic and 53.44 tones/year for overseas flight.

As the result of the study in industrial sector, the factories were in northern part of Thailand emitted pollutants including Sulfur dioxide (SO_2), Nitrogen dioxide (NO_x), Carbon monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOC), Coarse Particulate Matter (PM10), and Fine Particulate Matter ($PM_{2.5}$) into the atmosphere about 39.00, 17.89, 6.64, 0.59, 21.45 and 14.41 gigagram/year respectively. The majority of them were utilized in a coal-fired power plant especially Mae-Moh power plant located in Lampang province. Due to the fact that lignite is a one type of fossil fuel, when it is burned, it emits sulfur dioxide, nitrogen oxides, particulates, carbon dioxide, mercury, and other heavy metals, as well as fly ash and bottom ash. In 2019, Mae-Moh power plant released gas pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), ammonia (NH_3), methane (CH_4), organic carbon (OC), and black carbon (BC) into the atmosphere in the amounts of 498.03, 332.02, 166.01, 166.01, 176.6 and 0.332 Gg/year respectively. In term of particulate matter, it was emitted from this sector about 164.68 Gg/year both PM_{10} and $PM_{2.5}$.

Open burning of agricultural residue waste released gas pollutants such as Sulfur dioxide (SO_2), Nitrogen dioxide (NO_x), Carbon monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOC), Ammonia (NH_3), Methane (CH_4), Organic carbon (OC), and Black carbon (BC) into the atmosphere following 5.50, 15.45, 1,013.04, 79.53, 38.74, 89.55, 91.51, and 8.07 in unit of gigagram/year respectively while particle pollutant such as PM_{10} and $PM_{2.5}$ were emitted about 96.85 and 86.68 gigagram/year. Rice is a significant source of emissions in the study area because it is Thailand's primary economic crop while sugarcane was the second crop type that contributed to air pollution. In the case of sugarcane, framers will burn the crop prior to harvesting to increase the harvesting process's efficiency, as sugarcane leaves can be obstructive. While the forest fire sector emitted CO into the atmosphere an estimated about 11,769 tons per year in 2019, while forest fires emitted aerosols such as $PM_{2.5}$ and PM_{10} at an estimated 1,029 and 961.96 tons per year, respectively. Additionally, forest fires emitted methane, nitrous oxide, black carbon, and organic carbon about 769.57, 22.63, 74.69, and 588.49 tones/year respectively.

Residential emission inventory in the northern part of Thailand emitted pollutants into the atmosphere in the form of Sulfur dioxide (SO_2), Nitrogen dioxide (NO_x), Carbon monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOC), Ammonia (NH_3), Methane (CH_4), Black Carbon (BC), Organic Carbon (OC), Coarse Particulate Matter (PM_{10}), and Fine Particulate Matter ($PM_{2.5}$) about 0.074, 0.04, 5.75, 0.40, 0.053, 0.49, 0.08, 0.17, 0.53, and 0.47 gigagram/year respectively.

3.3 Spatial Distribution of Emission Inventory in the Northern Part of Thailand

The spatial distribution mapping (Figure 3) was developed based on five sectors including on-road, aircraft, agricultural, residential and forest fire sector. the grid with the highest emissions was in Lampang province because Mae Moh coal fired power plant is the major sources of emission while spatial distribution of emission in Chiang Mai provinces where

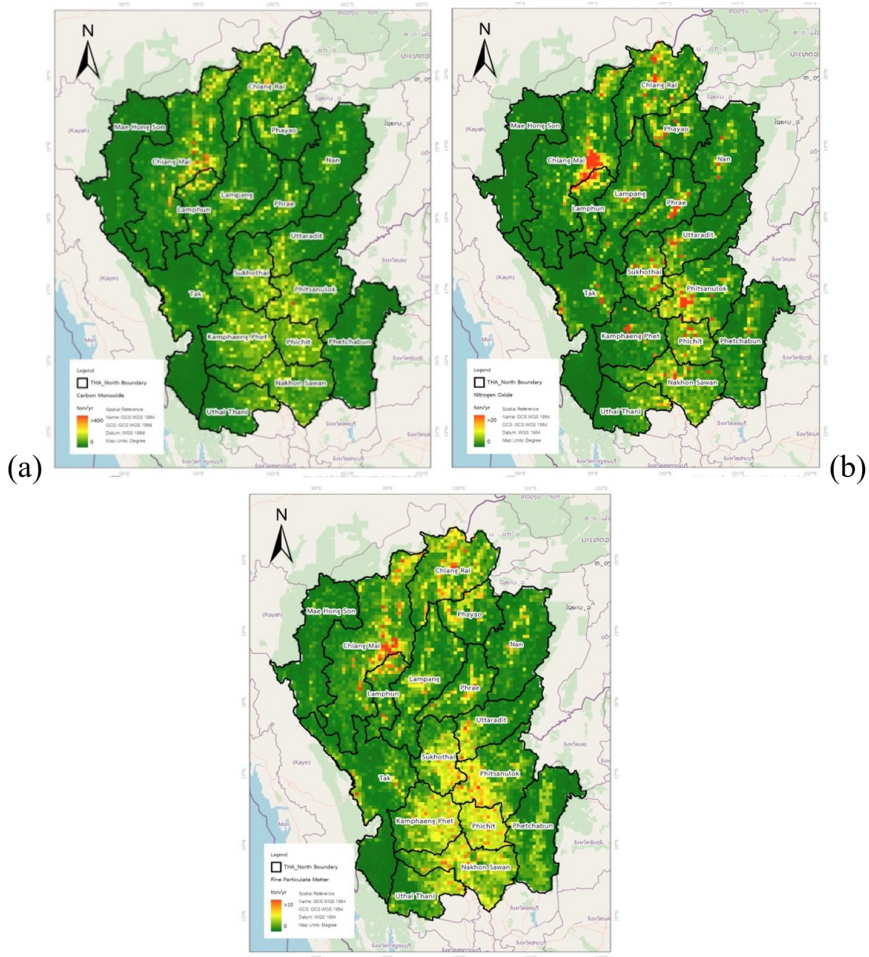

Figure 3 Spatial distribution of emission inventory in the norther part of Thailand by pollutant: (a) Carbon monoxide (b) Nitrogen oxide (c) Fine particulate matter or $PM_{2.5}$

is the center city of anthropogenic activity approximated 300 - 400 tons per grid per year for carbon monoxide emission. Moreover, the emission inventory of another pollutant, the highest emission was in Chiang Mai as well as carbon monoxide emission because most of the activity data, as much as the study can find out, occurred in this province higher than another.

4. Conclusion

This study aims to estimate the emission inventory based on secondary data provided by local government and private sector using the method of UNEP's Atmospheric Brown Clouds – Emission Inventory Manual. The focused pollutants include Sulfur dioxide (SO_2), Nitrogen dioxide (NO_x), Carbon monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOC), Ammonia (NH_3), Methane (CH_4), Black Carbon (BC), Organic Carbon (OC), Nitrous oxide (N_2O), Coarse Particulate Matter (PM_{10}), and Fine Particulate Matter ($PM_{2.5}$) in the northern part of Thailand. In 2019, these pollutants were emitted into the atmosphere about 10,179.34, 957.53, 1,910.08, 250.87, 39.27, 103.71, 13.07, 95.13, 0.38, 157.59, and 140.07 gigagram per year

On road transportation source play a role key of NO_x emission in the study area. urban area would have NO_x emission higher than another land use type due the high road

density per grid. While most of pollutant will coming from the incomplete combustion such CO and aerosol were high in the crop land area. Carbon Monoxide (CO) is the most prevalent gas pollutant in the studied area. Crop production, the studies reveal, played a substantial impact in CO emission. It is responsible for around 74% of total emissions.

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