RELATIONSHIP ASSESSMENT BETWEEN PM_{10} FROM THE AIR QUALITY MONITORING GROUND STATION AND AEROSOL OPTICAL THICKNESS

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ABSTRACT:

The northern part of Thailand always has PM_{10} exceeding the standard value which causes danger to public health. Major cause arises from open burning and forest fires, in addition, its meteorology and topography are likely to accumulate PM_{10}. This study aims to determine the relationship between PM_{10} quantity from the ground station and Aerosol Optical Thickness (AOT) from the Terra Satellite-MODIS system in Chiang Mai province in northern Thailand. The operations are 1) analyze data of PM_{10} and AOT, 2) analyze the statistical relationship in five models, namely exponential models, linear models, logarithmic models, polynomials models, and power models, and 3) PM_{10} and spatial AQI. The result found that it has a consistency between PM_{10} and AOT and PM_{10} and spatial AQI. The statistical relationship in five models found that January has the most R^2 in polynomials models, February has the most R^2 in logarithmic models, March has the most R^2 in power models, and April has the most R^2 in linear models and polynomials models.

Keywords: *Air pollution, PM_{10}, Remote Sensing, Aerosol Optical Thickness*

1. INTRODUCTION

Progress and technological development increase constantly lead to the expansion of the industrial sector. Further the increase in population, the needs of humans also increase, including the fourth requisites, values, beliefs, culture, and traditions are increase and decrease according to the time (Sumungkalo, 2017). From human needs, inventions are created to facilitate human and cause more pollution in terms of air pollution, water pollution, noise pollution, and odor pollution (Kasetsart University, 2023). The increase of such pollution initiates particulate matter in the atmosphere and affects people such as respiration, transportation, and health and most of the causes arise from humans such as particulate matter from industrial estate operations, vehicles, and so on (BBC News, 2023).

Air pollution is an essential environmental problem in Thailand that originates from human activities such as open burning, communication, transportation, construction, industrial plants, and so on (Seinfeld, 1986; Pochanart et al., 2001; Kongpon & Srithawira, 2016). The report on air pollution in the area of Thailand found that particulate matter is the first significant air pollution problem (Mahidol University, 2023) and accumulated particulate matter in Thailand is ranked 11^{th} in the world (Thecitizen, 2023). A report on the pollution situation in Thailand found that air pollution is a major problem, especially the problem of particulate matter less than 10 Microns (PM_{10}). It can be either solid or liquid and invisible, the size of invisible particulate matter is 0.002 µm up to larger than 500 µm (Nguyen et al., 2017; Kanjanasiranont et al., 2022; Silva et al., 2022), and visible particulate matter has a size of 50 Microns. The United States Environmental Protection Agency has determined the standard of small particles into two types which are PM_{10} as course particles and $PM_{2.5}$ as final particles (The United States Environmental Protection Agency, 2023).

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This research refers to PM_{10} which is course particles and its diameter is 2.5 – 10 µm. It arises from open burning, fuel combustion, industrial processes, grinding, milling, making as a powder from construction, and so on. The above-mentioned will affect health as it will accumulate in the respiratory system after inspiration (Air4thai, 2023). PM_{10}, also known as coarse particles, refers to airborne particulate matter with a diameter ranging from 2.5 to 10 micrometers. This type of particulate matter, when present in significant quantities, is often easily observable. Examples include dust particles adhering to surfaces, pollen from flowers, or airborne particles generated from construction activities (Air4thai, 2023). PM_{10} in Thailand has an impact more than the normal respiratory system as these particles are small enough to be absorbed in the bloodstream and get through the lungs. In daily life, human is unable to avoid particles both inside and outside the house, once it has accumulated, they will affect the respiratory system or allergy (The National Science Museum Thailand, 2023). The northern part of Thailand encounters a smog crisis every year. By following up smog situation in the study area using an automatic air quality monitoring station from the Pollution Control Department of Thailand found that the quantity of PM_{10} severely exceeds the standard from January to April every year (Pollution Control Department, 2022).

Currently developed technology is created to be used for many purposes and one of them is Remote Sensing Technology. Remote Sensing Technology has physical principles of electromagnetic waves to acquire information without making physical contact with objects. It has three components which are Spectral, Spatial, and Temporal component (ESA, 2016; Elachi & Zyl, 2021; The University of Lucknow, n.d.). However, using Remote Sensing Technology under satellite data applications can survey a wide area and cost less than ground survey, therefore this technology has been used extensively in various studies on natural resources and the environment (Gomasathit et al., 2015; Laosuwan et al., 2023; Phoophiwfa et al., 2023). In the past measuring particulate matter in the atmosphere could be done by measuring tools and sensors only (Pollution Control Department, 2023), later Remote Sensing Technology was used to measure the quantity of particulate matter by using data from natural resources and environment observation satellites. After researching documents and relevant research found that data from satellites has been used to estimate particulate matter in the atmosphere such as research on "Spatiotemporal Patterns of PM_{10} Concentrations over China during 2005–2016: A Satellite-based Estimation using the Random Forests Approach" by Chen et al., (2018), research on Patterns of Relationship between PM_{10} from Air Monitoring Quality Station and AOT Data from MODIS Sensor Onboard of Terra Satellite" by Suriya et al., (2021), research on "Estimation of Ground $PM_{2.5}$ Concentrations in Pakistan Using Convolutional Neural Network and Multi-Pollutant Satellite Images" by Ahmed et al., (2022), research on "The Human Health Risk Assessment of Particulate Air Pollution ($PM_{2.5}$ and PM_{10}) in Romania" by Bodor et al., (2022), and research on " Estimation of Particulate Matter Less Than 10 Microns Volume through Various Formats of Spatial Interpolation Methods" by Itsarawisut & Laosuwan (2022).

This research is an assessment of the relationship between PM_{10} from the ground station and Aerosol Optical Thickness (AOT) from the Terra Satellite-MODIS system from January to April 2022 in Chiang Mai province, the northern part of Thailand.

2. MATERIALS AND METHODS

2.1. Study Area

Chiang Mai Province (**Fig.1**) is a province in the northern part of Thailand, its area covers 20,107 km^2 which is the second largest province in the country and has a population of approximately 1.76 million people which is the fifth largest amount in the country. The general topography is mountain and grove wood and has plains in the middle along Ping River. The highest mountain in Thailand is Doi Inthanon located in Chom Thong District with a height is approximately 2,565 meters. In addition, other mountains that have lower heights are Doi Pha Hom Pok (Fang District) with a height is 2,285 meters, Doi Luang Chiang Dao (Chiang Dao District) with a height is 2,170 meters, Doi Suthep (Mueang Chiang Mai District) with a height is 1,601 meters.

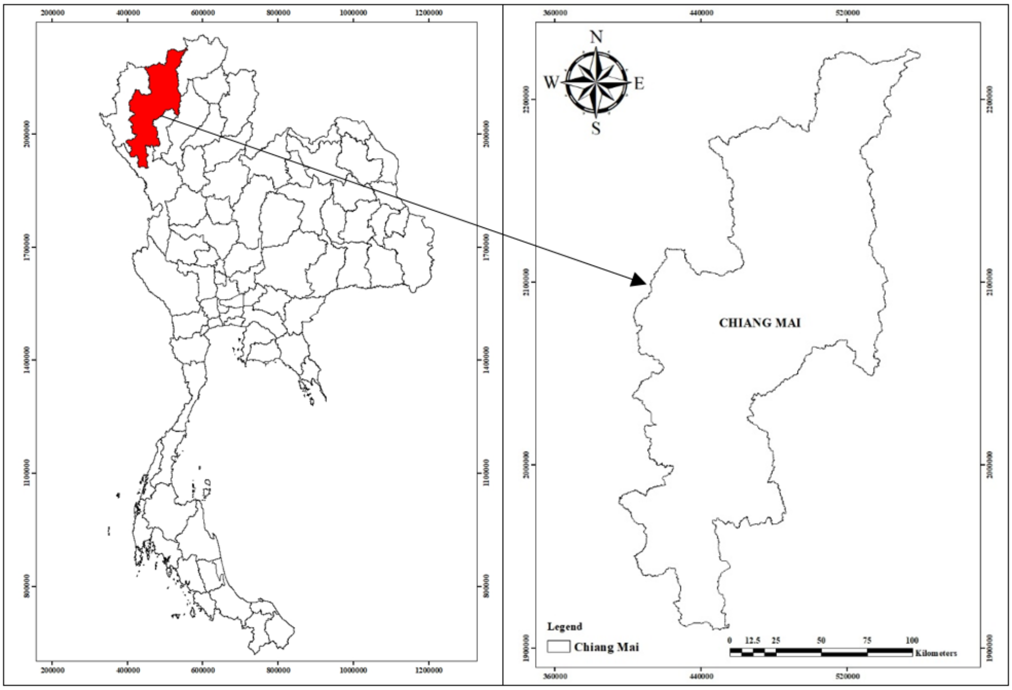


Fig. 1. The Study area.

The climate in Chiang Mai has an average temperature throughout the year is 25.4°C, an average maximum degree is 31.8 °C, an average minimum degree is 20.1°C and an average rainfall is 1,-100 1, 200millimeters. Chiang Mai will confront two monsoons; southwest monsoon and northeast monsoon. Its climate is divided into three seasons, namely summer, rainy, and winter.

2.2. Satellite data

Moderate-Resolution Imaging Spectroradiometer Sensor System or MODIS installed on the Terra Satellite is a spectrum radiometer developed from Advanced Very High-Resolution Radiometer System or AVHRR installed on NOAA Satellite. MODIS sensor is designed to monitor and detect natural resources and the environment of the earth at the regional level. MODIS data has Swath approximately 2,330 Km, it can record data that covers the area around the world every 1-2 days and record data for 36 different bands that have wavelengths from 0.4-14 µm.

MODIS Sensor System has product data that is divided into four levels, namely Level 0, Level 1, Level 2, and Level 3. Data from Level 2 product consists of five products, namely 1) Aerosol products and optical properties data, 2) Atmospheric water vapor data, 3) Physical properties of cloud, 4) Atmosphere profile product, and 5) Cloud mask products where Aerosol Products (MOD04_L2) represents Aerosol Optical Thickness or AOT both on the land and in the sea and it is Near-real time product.

2.3. Operation

The study on relationship assessment between PM_{10} from the ground station and AOT from the Terra Satellite-MODIS system has the process in **Fig. 2**.

2.3.1. Data of PM_{10}

A researcher gathers data from monitoring and detecting PM_{10} from the air quality monitoring ground station from January to April 2022 between 10.00-11.00 am. from a monitoring station at Chang Phueak Sub-district, Mueang District, Chiang Mai Province. PM_{10} criteria in Thailand are shown in **Table 1**.

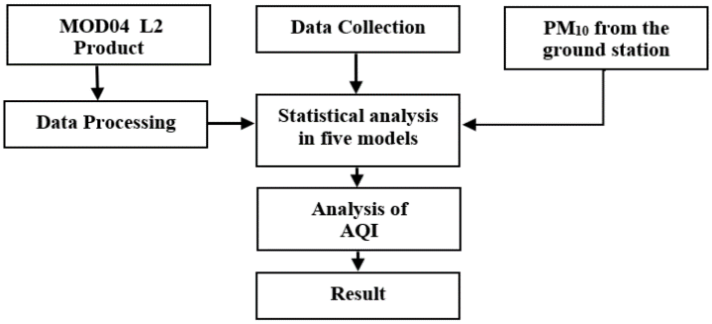


Fig. 2. Flowchart of the study.

2.3.2. MODIS Data (MOD04_L2 Product)

AOT data from measuring by MODIS Sensor can be downloaded from LAADS Web at https://ladsweb.modaps.eosdis.nasa.gov/search/order/1/MOD04_L2--61 and use package software to open data. MODIS AOT Data used as data in the product of Level2 named MOD04_L2 from 10.00-11.00 a.m. (Local time UTC+7).

2.3.3. Analysis of the statistical relationship

This research has analyzed the statistical relationship between PM_{10} from the air quality monitoring ground station and Aerosol Optical Thickness (AOT) from the Terra Satellite-MODIS system to determine the relationship by analyzing the statistical relationship in five models, namely exponential models, linear models, logarithmic models, polynomials models, and power models.

2.3.4. Analysis of Air Quality Index (AQI)

AQI is a report of air quality that is easy to understand and disseminate to the public to be aware of air pollution in each area in terms of severity and health impact (Please see **Table 1**: AQI criteria in Thailand).

Table 1.

AQI criteria in Thailand (Air4thai, 2023).

PM_{10} (µg./m^3) Continuous 24 hour average	meaning	Colors used	Guidelines for preventing impacts
0-50	Very good	Blue	No health effects
51-80	Good	Green	No health effects
81-120	Moderate	Yellow	Patients with respiratory disease should avoid exercising outdoors. The general public, especially children and the elderly, should not engage in outdoor activities for long periods of time
121-180	Starting to affect health	Ornage	Patients with respiratory disease should avoid exercising outdoors. The general public, especially children and the elderly, should not engage in outdoor activities for long periods of time
181and up	Affects health	Red	The general public should avoid exercising outdoors. For patients with respiratory disease should stay indoors

3. RESULTS AND DISCUSSION

3.1. Analysis result of PM_{10} and AOT data

Analysis result of PM_{10} from the air quality monitoring ground station at Chang Phueak Sub-district, Mueang District, Chiang Mai Province from January to April 2022 and analysis result of AOT data from the Terra Satellite-MODIS system shown from Table 2 to Table 4 found that January has a maximum average of PM_{10} on January 30 which is 71 µg/m^3, February has a maximum average of PM_{10} on February 13 which is 123 µg/m^3, March has a maximum average of PM_{10} on March 24 which is 282 µg/m^3, and April has a maximum average of PM_{10} on April 2 which is 185 µg/m^3. Comparing AOT data with PM_{10} from the ground station found that if AOT value decreases, then PM_{10} value decreases, on the other hand, if AOT value increases, then PM_{10} value increases as well. The analysis of PM_{10} can identify air quality that affects health and sanitation air quality index affects health and sanitation.

Maximum PM_{10} in each month will affect health as follows: January (**Table 2)** has an average PM_{10} in green level which means people can do outdoor activity and travel as usual, February (**Table 3)** has PM_{10} in orange level which causes health impact, people should be aware of their health. If initial symptoms occur such as cough, difficulty breathing, or eye irritation, outdoor activity should be reduced, or use self-protection equipment as necessary.

Table 2.

AOT and PM_{10} values for January.

Date	AOT	PM_{10} (µg/m^3)	Date	AOT	PM_{10} (µg/m^3)
1	0.136	43	17	-	36
2	0.134	42	18	0.127	48
3	0.131	40	19	-	53
4	0.128	41	20	0.193	56
5	0.115	36	21	0.124	46
6	0.132	40	22	-	43
7	0.141	44	23	0.201	59
8	0.128	49	24	-	55
9	-	28	25	0.192	55
10	0.121	40	26	-	46
11	0.122	40	27	0.191	55
12	0.142	44	28	0.423	69
13	0.141	43	29	0.421	67
14	0.119	38	30	0.432	71
15	0.138	43	31	0.431	70
16	0.123	41			

Table 3.

AOT and PM_{10} values for February.

Date	AOT	PM_{10} (µg/m^3)	Date	AOT	PM_{10} (µg/m^3)
1	0.322	61	15	0.341	68
2	0.391	65	16	0.404	76
3	0.324	63	17	0.401	75
4	-	44	18	0.321	60
5	-	42	19	0.346	79
6	-	42	20	0.313	83
7	0.229	48	21	0.315	86
8	0.229	49	22	0.317	86
9	0.225	48	23	0.481	90
10	0.22	46	24	0.511	92
11	0.301	52	25	0.345	78
12	0.401	76	26	0.464	85
13	1.629	123	27	0.491	90
14	0.345	79	28	0.819	102

Table 4.

AOT and PM_{10} values for March.

Date	AOT	PM_{10} ($\mu g/m^3$)	Date	AOT	PM_{10} ($\mu g/m^3$)
3	0.221	74	7	-	-
4	0.227	74	8	0.236	84
9	0.226	74	21	0.422	83
10	0.389	85	22	0.421	106
11	-	-	23	2.086	207
12	0.941	142	24	2.263	282
13	0.923	182	25	0.966	198
14	0.605	160	26	0.954	144
15	0.926	186	27	0.568	122
16	2.095	208	28	0.769	125
17	0.883	144	29	0.695	118
18	-	-	30	1.341	216
19	0.574	122	31	2.103	231
20	0.451	89			

Anyone who needs special health care should reduce outdoor activity or use self-protection equipment as necessary. If health symptoms occur such as cough, difficulty breathing, eye inflammation, oppression in the chest, headache, irregular heartbeat, nausea, or fatigue should consult a doctor. March (**Table 4)** and April have PM_{10} in red level, people should avoid outdoor activity and areas with high air pollution or use self-protection equipment as necessary. If health symptoms occur should consult a doctor.

3.2. Analysis result of the statistical relationship

Analysis result of the statistical relationship between PM_{10} from the air quality monitoring ground station and AOT from the Terra Satellite-MODIS system to determine the relationship by analyzing the statistical relationship in five models, namely exponential models, linear models, logarithmic models, polynomials models, and power models can be described in **Table 5**.

Table 5.

Analysis result of the statistical relationship.

Statistical relationship	Coefficient of Determination (R^2)			
	January	February	March	April
Exponential models	0.8065	0.4673	0.787	0.8636
Linear models	0.8624	0.5967	0.8453	0.8949
Logarithmic models	0.917	0.7705	0.8703	0.8792
Polynomials models	0.94	0.7603	0.8902	0.8949
Power models	0.8749	0.6855	0.9072	0.8764

Exponential models analysis explains that the relationship between AOT and PM_{10} in January has equation $y = 34.712e^{1.702x}$ and has a coefficient of determination)R^2(equals 0.8065 which a coefficient of determination is more than 0.7 means an excellent relationship as it is close to 1, in February has equation $y = 55.474e^{0.6258x}$ and has a coefficient of determination)R^2(equals 0.4673 which a coefficient of determination is less than 0.5 means a poor relationship as it is not close to 1, in March has equation $y = 77.958e^{0.5854x}$ and has a coefficient of determination)R^2(equals 0.787 which a coefficient of determination is more than 0.7 means an excellent relationship as it is close to 1, and in April has equation $y = 67.792e^{0.7195x}$ and has a coefficient of determination)R^2(equals 0.8636 which a coefficient of determination is more than 0.7 means an excellent relationship as it is close to 1.

3.3. Analysis result of PM_{10} and spatial AQI

The analysis result of PM_{10} and spatial AQI from AOT data from the Terra Satellite-MODIS system from January to April 2022 is shown in **Fig. 3** and **Fig. 4**.

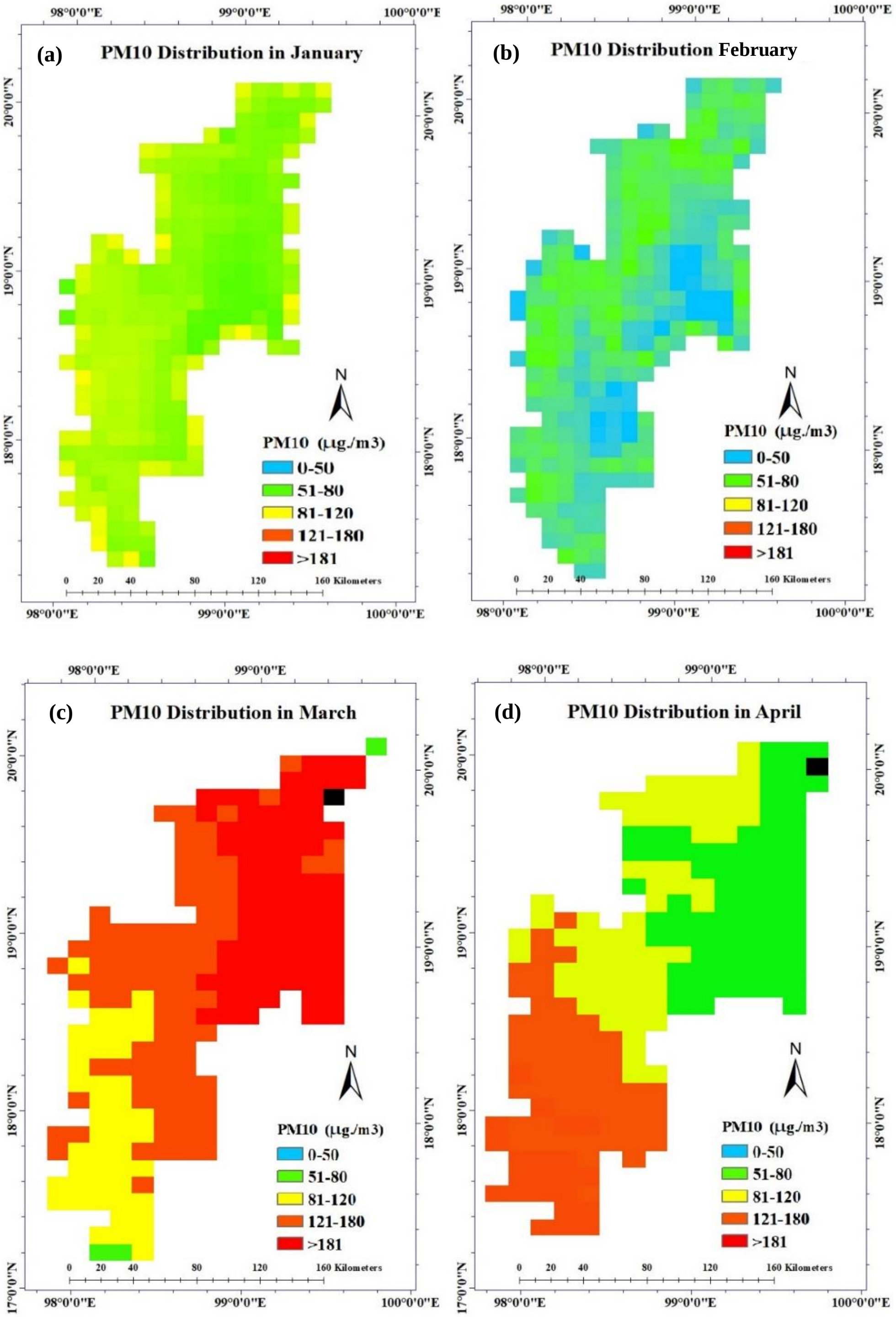
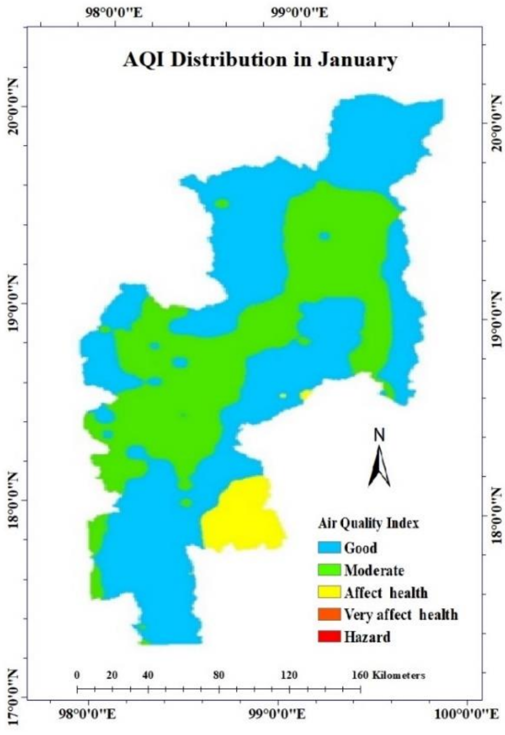
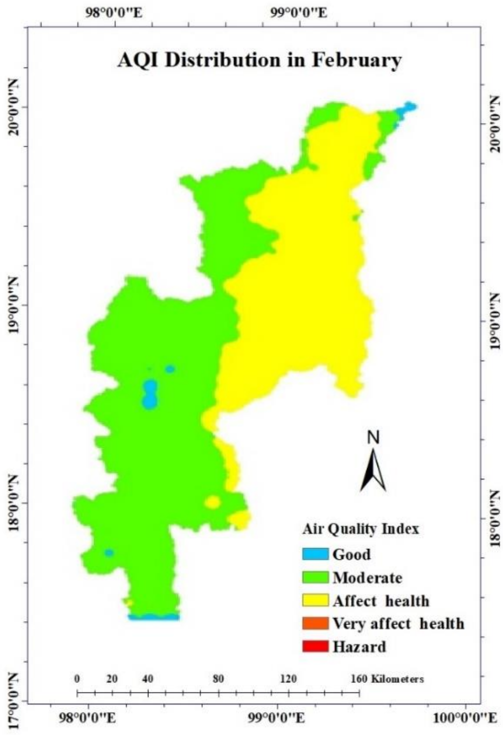


Fig. 3. Analysis result of PM_{10}.



(a)



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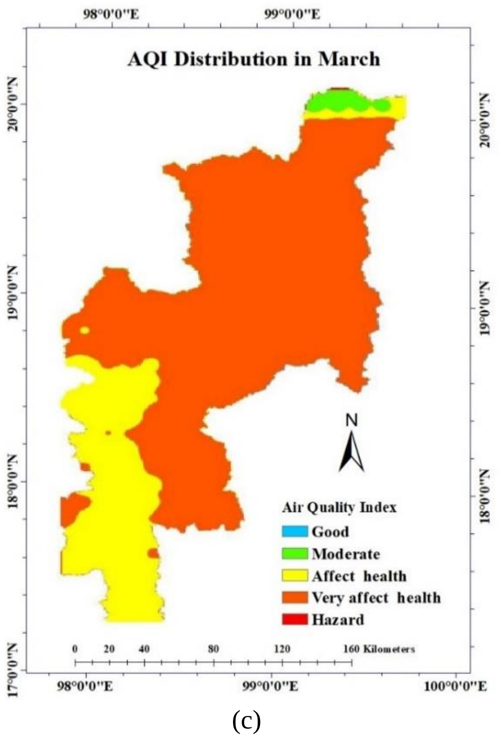

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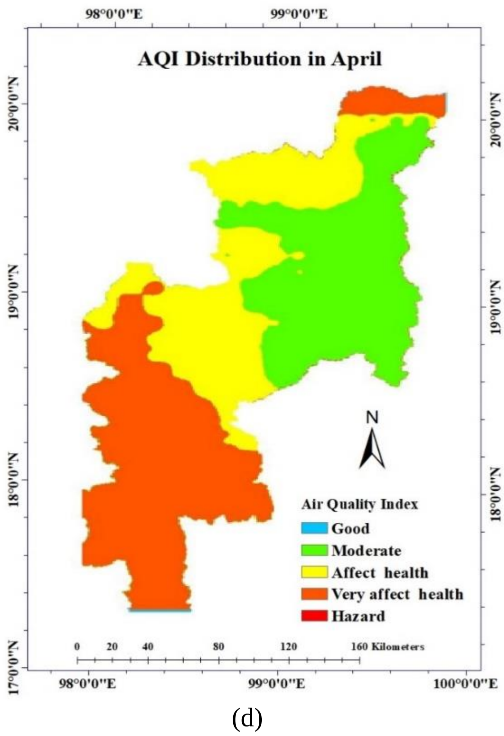

(d)

Fig. 4. Analysis result of AQI.

The analysis result of PM_{10} and AQI in January has conformity as most of PM_{10} and AQI are at an excellent level and suitable to do outdoor activity and travel, in February found that most of PM_{10} and AQI are at a good level and outdoor activity and travel as usual, in March and April found that most of PM_{10} and AQI will affect health, people should be aware of their health. If initial symptoms occur such as cough, difficulty breathing, or eye irritation, outdoor activity should be reduced, or use self-protection equipment. Anyone who needs special health care should reduce outdoor activity or use self-protection equipment as necessary. If health symptoms occur such as cough, difficulty breathing, eye inflammation, oppression in the chest, headache, irregular heartbeat, nausea, or fatigue should consult a doctor.

4. CONCLUSIONS

The relationship assessment between PM_{10} from the ground station and AOT found that Chiang Mai has a moderate concentration of particulate matter but still affects health in some areas, especially during rush hours with heavy traffic or during agricultural season which leads to PM_{10} accumulation higher than other area. Analysis result of PM_{10} summarized as follows: January has a maximum average of PM_{10} on January 30 which is 71 µg/m^3, February has a maximum average of PM_{10} on February 13 which is 123 µg/m^3, March has a maximum average of PM_{10} on March 24 which is 282 µg/m^3, and April has a maximum average of PM_{10} on April 2 which is 185 µg/m^3. In addition, the study found that the Terra Satellite-MODIS system has the potential to detect PM_{10} by applying AOT data to determine the statistical relationship in five models, namely exponential models, linear models, logarithmic models, polynomials models, and power models where each model provides a coefficient of determination (R^2) in good condition (more than 0.5) and model with the most R^2 is considered as a proper model. Models that have the most R^2 in January are polynomials models, in February are logarithmic models, in March are power models, and in April are linear models and polynomials models. However, there are several limitations in this study. For example, data from ground-level air quality monitoring stations and information from the MOD04_L2 Product are not available on certain days of each month, which may result from sensor malfunctions or unfavorable weather conditions. For future studies, it is advisable to investigate other factors that influence the concentration of PM_{10}, such as wind direction, relative humidity, and temperature. Considering these additional factors will enhance the accuracy of predicting PM_{10} levels.

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