Smoke Haze Problem and Open Burning Behavior of Local People in Chiang Rai Province *

Nion Sirimongkonlertkun[1]**

[1]Department of Civil and Environment Engineering, Faculty of Engineering,Rajamangala University of Technology Lanna ChiangRai ,Thailand

Abstract

This research aims to study the relationship between air quality and open burning behavior of local people in Chiang Rai Province. In the analyzing process, concentrations of Particle Matter or PM_{10} levels data documented by Pollution Control Department and the results from a field survey in 2012 were used as key parts. In addition, hotspot data obtained from MODIS Satellite System was used to represent fire occurrence. Satellite images from Landsat 5 TM 2007 was also brought in to be compared with the satellite images of the year 2010, the most critical year, in order to discover burned areas. Statistics of monthly average of PM_{10} and average number of hotspot occurrences from January - April in 2008 – 2012 were employed to compare the relationship between them. As a consequence, their pattern relationship was found to have a relatively similar trend. Moreover, by using supervised classification, the satellite images showed that in 2007 and 2010 the burned areas in Chiang Rai were 4,340 km^2 or 37.46% and 4,386 km^2 or 37.86% of the total provincial area respectively. From the field survey, it was found that most of these areas were repeated burning sites, mainly located in the forest where agricultural burning was normally conducted. Therefore, changing land use to minimize open burning is most likely another possible option to solve the smoke haze problem in Chiang Rai.

Keywords: Hotspot/ MODIS/Landsat 5 TM/Chiang Rai /Open-Burning/ Haze

1. Introduction

Smoke haze that annually blankets the whole of Chiang Rai Province, especially in March has become the latest trend that directly affects the air quality as well as brings about adverse health impacts to local people. The major cause of smoke haze situation is a result of open burning, particularly the burning of agricultural residues conducted in forest areas. Located in the flat alluvial plain, where most of the terrain is either flat or has moderate hills with many rivers flowing by, Chiang Rai is considered one of the best areas for agriculture. Most of the people in either flat, or mountainous areas mainly caryy out agricultural activities, especially annual crops like rice, corn, beans, etc. The farmland in Chiang Rai is approximately 35.40% of the total land area. The majority of farmland is rice fields where farmers can plant rice twice a year. This starts in May to August and continues to the harvest season in November and December. After that, most of the farmers usually dispose of agricultural waste by burning rather than plowing, since it is an easy, convenient and faser tt way to prepare land for the next cultivation. Furthermore, they believe that burning agricultural waste can best increase fertility while also treating the soil and killing pests. People living in the highland and forest areas also earn their living by hunting. Fires which are normally set while hunting can easily lead to forest fires. Conclusively, without the construction of proper firebreaks, both kinds of burning can simply result in major forest fires. (Kasemsan Manomaiphiboon,2007; Sirimongkonlertkun and Phonekeo, 2012). At present, to solve the smoke haze problem in Chiang Rai ,there are many organization , both private and public sectors, taking part in policies and planning with the goal of reducing open burning. However, due to the lack of appropriate cooperation between both sectors, there is still no concrete operational plan or any measurement (Provincial Offices for Natural Resources and Environment Chiang Rai, 2010). The deficiency of integrated information about open burning issues from all sectors is one of the key problems.As this research focuses on discovering the relationship between air quality and open burning issue, its result can be used in part for operation plans and policy making. Although both sectors have tried to reduce open burning, which is the main cause of the problem, a severe smoke haze situation still exists annually. Accordingly, to obtain an effective solution, they need to understand the burning pattern and area based burning behavior of the local people, which were included in this research. In analyzing this process, the records of hotspots, PM_{10} levels, and field survey results were used as the main data. Plus, remote sensing and GIS were compared to determine the change of the burned areas in 2007 and 2010. Consequently, research results and its conclusions can be used in considering policy and in reference to reducing open burning.

2. Material and Methods

2.1 Data used in the research

2.1.1 The monthly statistics of PM_{10} levels (Particle Matter with the size less than 10 micron) from January to April in 2008 – 2012, recorded by Pollution Control Department.

2.1.2 Hotspot data in Chiang Rai detected from 2007 to April 30, 2012 by MODIS system, which

* This article support by Project of Hands-On Research and Development, Rajamangala University of Technology Lanna and Dr. Witoon Prommee is Mentor

**Corresponding author: E-mail: nionsiamgis@gmail.com

is installed on the satellite named Aqua and Terra. This data was obtained from the website: http://firms.modaps.eosdis.nasa.gov/firemap/.

2.1.3 Landsat 5 TM imagery in 2007 and 2010 obtained from Geo-Informatics and Space Technology Development Agency (Public Organization).

2.2 Methodology

Landsat 5 TM satellite images were classified to open burning areas (2007 and 2010) as described in following steps.

2.2.1.1 Read satellite image data from CD-ROM and then it was written to hard disk by using Imagine Software.

2.2.1.2 Satellite image data of the year 2007 and 2010 was geometrically collected by employing 16 ground control points (GCPs). These GCPs were collected from topography map with the scale of 1: 50,000 in UTM projection system, WGS 84, Zone 47. The registration in this process was second order polynomials with root mean square error less than 1 pixel and resampling to 25 meters per pixel applying nearest neighbor.

2.2.2 Processed Supervised Classification of satellite image by selecting Training Areas from burned areas and other land use types. Maximum Likelihood was used in data classification. In order to select Training Areas out of the data from the year 2010, it was necessary to consider the location of hotspot occurrences together with the map from Google Earth and the information taken from the field survey in 2010 to study the texture of burned areas as it showed on Landsat 5 TM satellite images. From the study, it was found that hotspots were mostlydetected on highlands where agriculture is generally conducted. Moreover, when analyzing False Color Composite images of Landsat 5 TM bands 453/RGB, it indicated that burned areas were in dark green color as displayed in Figure 1.

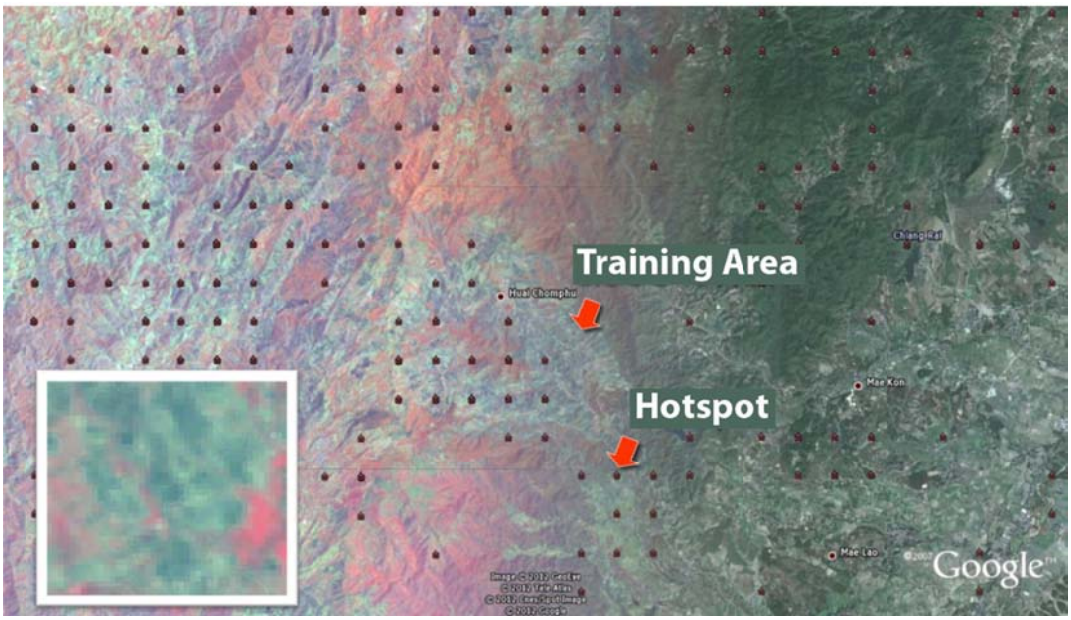

Figure 1: **Training areas for open burning**

2.2.3 Classification process of Landsat 5 TM satellite images in both 2007 and 2010 only focused on burned areas as the main target. In selecting the Training Areas, the researcher extracted the areas by repeating the interpretation step. After the first interpretation was done, the outcome was superimposed on satellite image data for visual comparison with the purpose of achieving the most accurate result.

2.2.4 In case that the classification accuracy was not acceptable, the classification process needed to be repeated again by increasing the Training Areas, in particular the burned areas. This process would be repeated until achieving the most accurate result. In this research, the classification process was repeated for five times, using more than 100 locations of Training Areas.

3. Results

3.1 The relationship between hotspot and PM_{10} levels.

Since the year 2007 (except 2009 and 2011, during which there were fluctuations of climate caused by La Niña, resulting in the increase of rain especially in March), people in Chiang Rai have to face a smoke haze situation in February and March annually. It is the period of time that PM_{10} levels exceed Thai national ambient air quality standards of 120 $\mu g/m^3$ for 24 hours. In addition, Chiang Rai was declared as a disaster zone on March 12, 2007 since PM_{10} levels exceeded the standard for several consecutive days. As a consequence, Pollution Control Department has installed two PM_{10} monitoring stations in Chiang Rai. Located at the Office of

Natural Resources and Environment, Chiang Rai (T65), the first station started monitoring in January 2009. The second station which started monitoring in July 2011 is located at the Health Office of Mae Sai Sub-district (T73). To visualize the relationship between the number of hotspots and PM_{10} levels, the related chart was created using the data from monthly averages of PM_{10} levels in January to April 2008 - 2012 and the monthly number of hotspots that occurred in Chiang Rai during the same period. The chart, as shown in Figure 2, revealed that the changes of monthly average of PM_{10} levels and monthly number of hotspots had the same pattern and trend. Also as indicated in the chart, monthly average of PM_{10} levels started to rise from November to April and then was relatively constant from May to October. Moreover, both hotspots and PM_{10} were found to peak in March of every year. In accordance with the study completed by Katesiri Leelasukultham, 2009, which concluded that the relationship between PM_{10} levels and the number of hotspots detected in Chiang Mai Province was significant (Kim and Leelasukultham, 2011). As well as the study made by Suthinee Dontree and et al, 2011, it was concluded that the change in the number of hotspots and air quality index in Chiang Mai were significantly related and followed the same pattern.

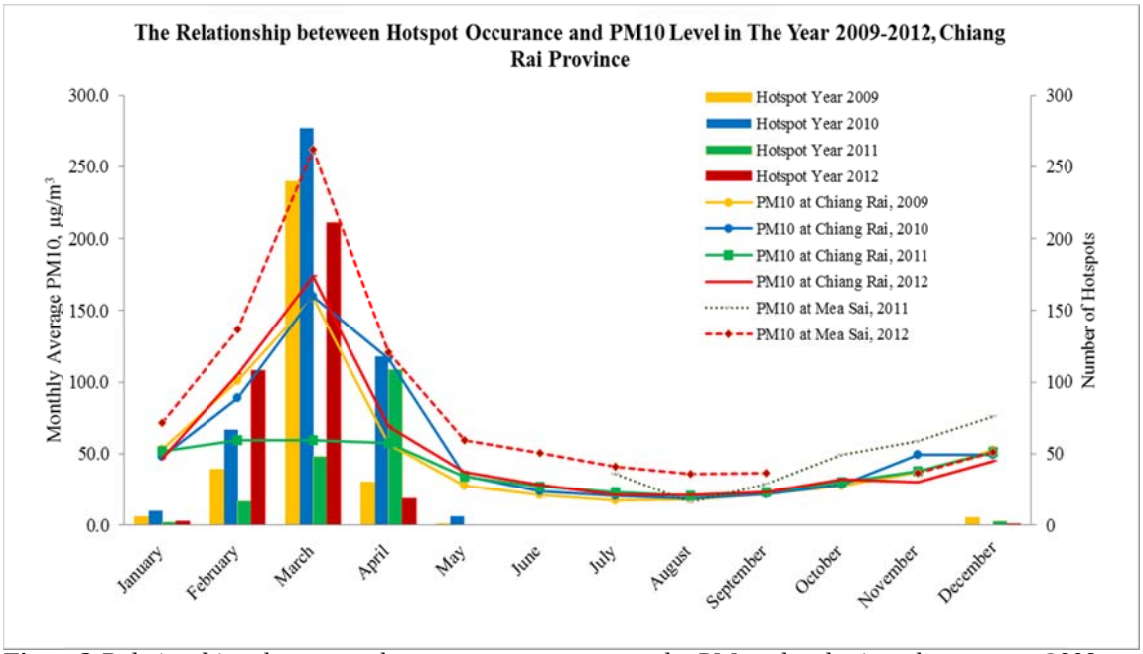

Figure2: Relationship between hotspot occurrence and PM_{10} level in the year 2009 – 2012

In the case of Chiang Rai, PM_{10} levels detected at station T73 (Health Office of Mae Sai Sub-district), it was found that the PM_{10} levels were nearly twice as high than the ones which were detected at station T65 (Office of Natural Resources and Environmental, Chiang Rai). In order to considerer the cause of this phenomenon, it should first be noted that the station T73 is located on the border areas between Thailand, Myanmar and Laos. Secondly, satellite images from MODIS sensor by NASA (National Aeronautics and Space Administration, 2012) showed that in March 2012, there were numbers of hotspots occurring in the areas of Chiang Rai and its neighbors including Myanmar and Laos. Moreover, based on the study by Bach and Sirimongkonlertkun, 2011, which studied the hotspot occurrence which represents the open burning activities of the countries in the Great Mekong Sub region(GMS), interestingly concluded that open burning is an important contributor of particulate matter pollution in the Northern region of Thailand during the dry season (January - April), especially in March. However, Thailand is not the only country that conducts burning during the dry season (January - April). Significant burning is also conducted in Laos and Myanmar. Moreover, most GMS countries experience the highest amount of burning during March of each year. This is in accordance with the increasing PM_{10} values in the upper northern region of Thailand during the same period (PCD, 2012). Apart from this, at the same period, the high PM10 concentration was detected when there was air mass movement in the southwestern direction (Sirimongkonlertkun, 2012), which moves over the area of a high number of hotspots in Myanmar before entering the territory of Thailand. Therefore, it can be said that the high levels of PM_{10} at station T73 might be partially influenced by open burning conducted in these two neighboring countries and neighboring provinces (Sirimongkonlertkun et al, 2013). Therefore, in order to solve the smoke and

haze, it should be considered not only in Chiang Rai province, but also in neighboring provinces and countries.

3.2 Burned areas in Chiang Rai, referenced according to satellite images from Landsat 5TM of the year 2007 and 2010.

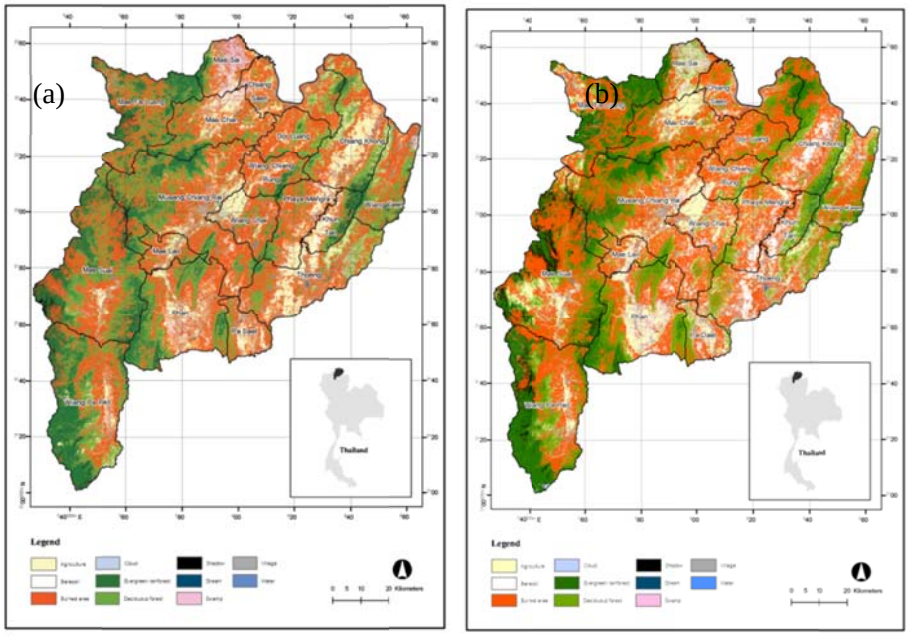

Figure 3:Burned areasclassification from Landsat TM 5 in 2007(a) and 2010 (b)

Table 1: The classification result of burned areas using satellite imagery from Landsat 5 TM from the year 2007 and 2010 through Supervised Classification method

Type of Land Use	2007		2010	
	Area (km^2)	Percentage	Area (km^2)	Percentage
Water Sources	25	0.22	21	0.18
Rivers	57	0.49	57	0.48
Wetlands	286	2.47	258	2.23
Open Area	213	1.84	61	0.52
Community	784	6.77	784	6.77
Burned Areas	4,340	37.46	4,386	37.86
Agriculture	1,429	12.34	2,023	17.47
Evergreen Rainforest	1,788	15.43	1,578	13.63
Deciduous Forest	2,529	21.83	2,168	18.72
Shadow	133	1.15	201	1.73
Clouds	-	0	47	0.41
Total	11,584	100.00	11,584	100.00

Due to satellite image classification, total burned areas in the year 2007 were 4,3402 km^2 or 37.46% of Chiang Rai's total area (Figure 3 and Table 1). The top ten burned areas, sorted by district included Muang, Mae Suai, Phan, Wiang Pa Pao, Thoeng, Mae Chan, Chiang Khong, Mae Fah Luang, Chiang Saen, and Phaya Mengrai. Additionally, in 2010, total burned areas were 4,386km^2 or 37.86% of Chiang Rai's total area. Top ten burned areas were found in the districts of Muang, Mae Suai, Wiang Pa Pao, Mae Chan, Phan, Chiang Khong, Thoeng, Mae Fah Luang, and Phaya Mengrai. Comparing between these two years, the burned areas in 2010 increased by 46 km^2 or 1.06% and top burned areas were within the same group of districts as subjected in 2007.In November 2011 to April 2012, the researcher conducted field surveys together with officers from Forest Fire Control Department, Mae Suai to inspect the actual burning situation in the study areas. both--plains and high lands. Muang District was selected to represent the plain areas whereas Mae Suai and Chiang Khong represented highland areas. As a consequence, open burning in Chiang Rai was generally conducted during two periods. The first period began in November to December when farmers burned rice stubbles after harvest season, in order to prepare their land for planting

soybean. The second period was in February and March when farmers burned agricultural residues to prepare the lands, mostly located on forest highland areas, for planting commercial crops, especially corn used for animal feed.I It was also found that without making proper firebreaks, these agricultural burnings easily spread out and became uncontrollable forest fires. Furthermore, with the need to get the lands well prepared prior to the Songkran Festival, the farmers in highland areas, were likely to conduct burning at the end of February and March. In coincidence with the Report on the Occurrence of Forest Fire in Chiang Rai, the incidence of forest fires peaked in March annually (Forest Fire Suppression and Control Office, 2012). However, burned areas decreased from 8 km^2 or more in some districts particularly Thoeng and Wiang Chai Districts. A field survey in Wiang Chai showed that rubber tree plantation has greatly increased. This can be implied that changing land use may be an option for reducing open burning since the planters must always be cautious about fires which can cause damage to their rubber trees.

4. Discussion

The smoke-and-haze problem from open space burning has a negative influence not only on the air quality, but also on the health of local people in the study area.(Barnett et al, 2005; Brunekreef and Forsberg, 2005 and Mongkol Rayanakorn. ,2010.) Therefore, the major purpose of this study is to identify the factors and relationships with regard to the open burning behaviors of the local people and its influence on the smoke and haze problem. The results obtained from the applied methodology in this study, which is derived from the analysis of spatial distribution of MODIS active fire hotspots (Low et al. (2005); Phonekeo et al. (2005) together with the analysis and estimation of the open burning area using high resolution satellite data which is Landsat TM 5, has shown the increase in the number of hotspots between two years, which corresponds with the increase of the burned areas in the province. Also, the open burning activities consistently occur in the same groups of districts.

Another important point that needs to be focused on is, even though open burning has increased by only 1.06% in 2010, compared to 2007 which is a relatively small percentage, the smoke and haze situation during the burning season in these years is considered to be serious. Since it has caused many problems to the local populations of the province, in particular health problems it also has a serious impact on the tourist industry and other socio-economical developments of the province. Therefore, the obtained results are good indicators that help to explain the open burning behavior of the local people, which has been monitored using remote sensing technology. It can be seen that it has a strong influence on the smoke and haze problem in the province. In order to have a better scenario of the open burning behavior and its relationship to the smoke and haze problem, it is suggested that a larger study be carried out using a longer time frame. This could provide a more efficient result and would be useful information for administrative planners and decision-makers.

5. Conclusion

In this study, the authors have studied the significant relationship between the increase in PM_{10} levels and open burning behaviors of local people. Besides, PM_{10} levels, which represents the concentrations of small dust particles in the air, this mainly peaked in March when open burning was mostly conducted. According to satellite image classification of the years 2007 and 2010, interpretation results indicated that there was an increase of open burning by 1.06% in 2010. In addition, most of the burning was repeatedly conducted in the same areas, especially in the forest, with the purpose of preparing the land for next cultivation. These facts can best reflect burning behavior of local people in Chiang Rai. However, in the case that some burning areas have decreased in some districts, it might be the result of changing land use of local people, as the lands were used to plant rubber trees instead of annual crops. Therefore, changing land use should be considered as an option for reducing open burning which is the major cause of the smoke haze problem.

6. Acknowledgement

The authors would like to especially like to thank Thai Universities for Public Health Policies for sponsoring all research funds. Gratitude also goes to every agency that provided data and information involved. For example, the National Aeronautics and Space Administration (NASA) provided the readily available fire data from the Fire Information for Resources Management System (FIRMS; http://maps.geog.umd.edu/firms) at the University of Maryland. Plus, the Pollution Control Department (PCD) of Thailand provided PM_{10} data and the Geo-Informatics and Space Technology Development Agency (Public Organization) provided data from Landsat 5 TM.They also take this opportunity to acknowledge the cooperation of Forest Fire officers and local residents for providing social information which helped make this research more complete.

7. References

Adrian G. Barnett, Gail M. Williams, Joel Schwartz, Anne H. Neller, Trudi L. Best, Anna L. Petroeschevsky & Rod W. Simpson. (2005). **Air Pollution and Child Respiratory Health A Case-Crossover Study in Australia and New Zealand**. American Journal of Respiratory and Critical Care Medicine, Vol 171, 1272-1278. Available

http://ajrccm.atsjournals.org/cgi/content/short/171/11/1272 Accessed on August 30, 2010

Bach, N.L. and Sirimongkonlerkun N. 2011. Satellite Data for Detecting Trans- Boundary Crop and Forest Fire Dynamics in Northern Thailand. **Int. J. Geoinformatics**, *2011*(7), 47-53.

Brunekreef.B.& Forsberg. B. (2005). Epidemiological evidence of effects of coarse airborne particles on health. **European Respiratory Journal**, 26, 309-318.

Dontree S., Thumtakhop S., Chamniwikaiyapong P. &, Noisuya S., 2011. **Prioritizing of Burned Areas using Multi-Source Spatial Data for Open Field Burning Surveillance and Prevention in Chiang Mai Province**. Chiang Mai: Chiang Mai University.

Forest Fire Suppression and Control Office. 2012. **The Conclusion on Operational Results Chiang Rai Forest Fire Operation Center Fiscal Year 2012**. Chiang Rai: Forest Fire Operation Center.

Kasemsan Manomaiphiboon1. (2007). **Examination of Potential Fire Emissions for a March-2007 Haze Episode in Upper Northern Region of Thailand Using Trajectory Modeling.** Paper presented at Asian-Pacific Regional Conference on Practical Environmental Technologies, KhonKaen, Thailand.

Kim O. and Leelasakutum K. 2011. Analysis of Meteorology and Emission in Haze Episode Prevalence over Mountain-Bounded Region for Early Warning. **The Science of the Environment.** 409, 2261-2271.

Leelasakutum, K. 2009. **The Chiang Mai Haze Episode in March 2007** (Master's Thesis). Asian Institute of Technology, Bangkok.

Low,Liew&Kwoh.(2005).**Environmental Monitoring of Southeast Asia using MODIS Direct Broadcast Data**. Retrieve July 25, 2012, from http://www.isprs.org/publications/related/ISRSE/html/papers/784.pdf.

NASA's Earth Observation System Data and Information System (EOSDIS). 2011 Active Fire Data. [Online] Available: https://earthdata.nasa.gov/data/near-real-time-data/firms/active-fire-data.

Mongkol Rayanakorn. (2010). **Haze and Air Pollution in Chiang Mai.** Available: http://www2.mahidol.ac.th/ks/vicharn/Haze-Airpollution.pdf Accessed on January 22, 2010.

Nion Sirimongkonlertkun. 2012. **Effect from Open Burning at Greater Mekong Sub-Region Nations to the PM_{10} Concentration in Northern Thailand: A Case Study of Backward Trajectories in March 2012 at Chiang Rai Province**.Paper presented at the 1st Mae Fah Luang University International Conference, 29-30 November 2012. Chiang Rai; Thailand 2012: 1-13.

Provincial Offices for Natural Resources and Environment Chiang Rai,2010. **Understanding about Smoke-and-Haze and Wildfire in Chiang Rai** (in Thai).

Sirimongkonlerkun, N. and Phonekeo V. 2012. Remote Sensing and GIS Application Analysis of Active Fire, Aerosol Optical Thickness and Estimated PM_{10} in the North of Thailand and Chiang Rai Province. **Proceeding of the 3rd International Conference on Environmental Science and Development; 5-7 January 2012**. Hong Kong, China 2012: 304-308.

Sirimongkonlertkul, N., Upayokhin P., and Phonekeo V. 2013 Multi-Temporal Analysis of Haze Problem in Northern Thailand: A Case Study in Chiang Rai Province**. Kasetsart Journal (Natural Science)**, 2013(47), 768-780.

The Pollution Control Department (PCD). 2012. **Haze pollution situation in the Northern region of Thailand** on March 14, 2012.[Online] Available: http://aqnis.pcd.go.th/webfm_send/1482.

VivaradPhonekeo ,KyawSannOo & LalSamarakoon. 2005.**Development of MODIS Information System for Forest Fire Monitoring in South East Asia**, Asian Association on Remote Sensing (ACRS) Ulaanbaatar, Mongolia.