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Influence of agricultural activities, forest fires and agro-industries on air quality in Thailand

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ABSTRACT

Annual and monthly-based emission inventories in northern, central and north-eastern provinces in Thailand, where agriculture and related agro-industries are very intensive, were estimated to evaluate the contribution of agricultural activity, including crop residue burning, forest fires and related agro-industries on air quality monitored in corresponding provinces. The monthly-based emission inventories of air pollutants, or, particulate matter (PM), NOx and SO_2, for various agricultural crops were estimated based on information on the level of production of typical crops: rice, corn, sugarcane, cassava, soybeans and potatoes using emission factors and other parameters related to country-specific values taking into account crop type and the local residue burning period. The estimated monthly emission inventory was compared with air monitoring data obtained at monitoring stations operated by the Pollution Control Department, Thailand (PCD) for validating the estimated emission inventory. The agro-industry that has the greatest impact on the regions being evaluated, is the sugar processing industry, which uses sugarcane as a raw material and its residue as fuel for the boiler. The backward trajectory analysis of the air mass arriving at the PCD station was calculated to confirm this influence. For the provinces being evaluated which are located in the upper northern, lower northern and northeast in Thailand, agricultural activities and forest fires were shown to be closely correlated to the ambient PM concentration while their contribution to the production of gaseous pollutants is much less.

Introduction

Biomass burning refers to the burning of existing and dead vegetation including that in forests and agricultural areas. Biomass burning related to agricultural activities, such as crop residue burning represents an important source of air pollutants in many countries, especially in developing countries (Levine et al., 1995; Badarinath et al., 2006; Zhang et al., 2011). Biomass burning contributes to more than 50% of the global emission of black carbon into the atmosphere (Bond et al., 2004), e.g., and particulate matters (PMs) from biomass burning affect, not only the environment, but also human health. In developing countries, especially in the Southeast Asia, open biomass burning is a common protocol for handling crops before and after harvesting: for controlling of crop residues and weeds in the field after harvesting is completed (Garivait et al., 2004; Tipayarat and Sajor, 2012). Thailand is an agricultural-based country and generates massive amounts of agricultural waste and the economic contribution of agriculture promises to increase remarkably in the future because of the increasing population as well as growing trade and agro-industries (Kasem and Thapa, 2012).

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According to the Forest Fire Control Division (FFCD) (2014), the main reasons for forest fires are the collection of forest products by local residents, e.g., mushroom and bamboo (37%), incidents (12%), agricultural land clearing before the next crop cultivation (11%), hunting (11%), animal farming (4%), illegal logging (1%) and others (24%). Many of the recorded forest fires, therefore, are related to human activities, especially to agricultural ones. This promises to result in a serious situation regarding the ambient environment and health risks because a significant amount of air pollutants are emitted from open burning in fields in agriculture and related forest fires.

The emission from biomass burning related to agriculture is not only from open burning in fields but also from further processing by agro-industries. Sugarcane is a typical example in Thailand. In the central, northern and north-eastern parts of Thailand, sugarcane is the leading commercial crop, which is used in agro-industry as a raw material for producing sugar and the level of production has been rapidly increasing by more than 100% during the last 10 years (Office of the Cane and Sugar Board (OCSB), 2014). This can be attributed to the need for renewable energy such as bioethanol and gasohol that is promoted by the Thai government. Most of the sugarcane is processed in sugar factories to produce two main products, namely, sugar and molasses. Sugarcane residue, after the squeezing process, or, bagasse, is used as a fuel for boilers to produce the energy needed to operate a sugarcane plant. Since boiler emissions cannot be controlled in many cases and because emission control devices are often inadequate, a large amount of air pollutants may be released during the production of sugar. However, the issue of how it affects the status of the ambient pollutants has not been fully evaluated.

As a tool to evaluating the above described emission of air pollutants from biomass burning in agricultural activities, forest fires and agro-industries and their contribution to the status of the environment, the emission inventory (EI) is useful and is used as a standard method (Intergovernmental Panel on Climate Change (IPCC), 2006; Miller et al., 2006). Most of the EI has been developed for primary pollutants such as particulate matter ($PM_{2.5}$ and PM_{10}), carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrogen oxides (NO_x) (US EPA, 2010). There are several databases such as Global Emission Inventory Activity (Graedel et al., 1993), Transport and Chemical Evolution over the Pacific (TRACE-P) (Streets et al., 2003) and Regional Emission inventory in Asia (REAS) (Ohara et al., 2007). These databases can also be used for Thailand and EIs have been reported by governmental sectors such as the Pollution Control Department in Thailand (Pollution Control Department (PCD), 1994) as well as by researchers (Kim Oanh et al., 2011; Cheewaphongphan and Garivait, 2013). However, even when these available databases are used, detailed information such as a monthly-based inventory is very base limited or quite uncertain. Such information is important in terms of evaluating the emission linked to agricultural activities that are actually related to the harvesting and open burning periods, which differ from province to province in Thailand. It is also important to determine the relation between the emission inventory and status of the ambient environment such as the monthly averaged concentration of air pollutants.

In this study, annual and monthly-based emission inventories in northern, central and north-eastern provinces in Thailand, where agriculture and related agro-industries are quite intensive, were estimated, in order to evaluate the contribution of agricultural activity including crop residue burning, forest fires and related agro-industries to the air quality monitored in the corresponding provinces. The monthly-based emission inventories of air pollutants, or, PM, NO_x and SO_2, for various agricultural crops were estimated based on information supplied from various provinces on the amounts of typical crops: rice, corn, sugarcane, cassava, soybean and potato that are produced using emission factors and other parameters of country-specific values taking into account crop type and the period for burning local residues. The estimated monthly emission inventory was compared with air monitoring data obtained at monitoring stations operated by PCD, Thailand for the validation of estimated emission inventory. As the most influential agro-industry in the regions of interest, the emission inventory related to a sugar factory which uses sugarcane as the raw material and its residue as boiler fuel was estimated in order to evaluate their contribution. This was done, in order to verify the contribution of crop residue burning and forest fires from the distribution of crops and transportation by air mass flow, the 24-hr backward trajectory of air mass arriving at an elevation of 50 m from the average ground level at the PCD station corresponding to monitored data was calculated for selected periods.

1. Methods

1.1. Estimation of the amount of pollutants emitted

1.1.1. Crop residue burning

The amount of emissions from agricultural open burning was estimated for each crop based on literature values (Table 1). Emissions of air pollutants from crop residue burning were calculated from the following equation (Streets et al., 2003).

$$E = \Sigma_{\text{crop}}(M \cdot \text{EF}) \quad (1)$$

where E (g) is the emission of each pollutant, M (kg) is the total amount of burned biomass, EF ($g/kg_{\text{dry mass}}$) is the emission factor of each air pollutant emitted from crop residue burning obtained from the country-specific value and available reported data (Table 2). M is defined as the amount of burned crop based on total crop production data:

$$M = P \cdot N \cdot D \cdot \beta \cdot F \quad (2)$$

where, P (kg) is the annual crop production, which was obtained from the Office of Agricultural Economics in Thailand (OAE) and available for each province in Thailand (Office of Agricultural Economics (OAE), 2015). N is the residue to crop ratio, D is the fraction of dry matter, β is the fraction burned in the field, and F is the crop-specific burn efficiency ratio, where these values from literature shown in Table 1 were used in the flowing discussion.

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