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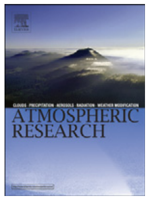

Effect of dramatic land use change on gaseous pollutant emissions from biomass burning in Northeastern China

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ABSTRACT

Biomass burning contributes a substantial amount of gas and particle emissions to the atmosphere. As China's breadbasket, northeast China has experienced dramatic land use change in the past century, converting approximately 55×10^4 ha of wetland into farmland to feed a rapidly growing population. This study combines measured emission factors of dominant crops (rice and soybean) and wetland plants (*Calamagrostis angu-stifolia*, *Carex lasiocarpa*, *Carex pseudo-curaica*) and remote sensing land use data to estimate the effect of the unprecedented land use change on gaseous pollutants emissions from biomass burning. Our biomass burning emission estimates resulting from land use changes have increased because of increased post-harvest crop residue burning and decreased burning of wetland plants. From 1986 to 2005, the total emissions of CO_2, CO, C_XH_Y, SO_2 and NO have increased by 18.6%, 35.7%, 26.8%, 66.2% and 33.2%, respectively. We have found two trends in agricultural burning: increased dryland crop residue burning and decreased wetland (rice paddy) burning. Our results revealed that the large scale land use change in northeastern China has induced more active biomass-burning emissions. The regional emission inventory of gaseous pollutants derived from this work may be used to support further examination of the subsequent effects on regional climate and air quality simulations with numerical atmospheric models.

1. Introduction

Biomass burning releases large qualities of gases and aerosol particles that, once emitted, alter the Earth's climate and degrade air quality (Andreae and Merlet, 2001; Reid et al., 2005; Vermote et al., 2009; Liu et al., 2014). In China, approximately 140 Tg of agricultural straws are burned every year, with larger amounts in the southeastern and northeastern regions (Cao et al., 2008). Emissions of carbonaceous particles from biomass burning were the largest source in the global troposphere (Akagi et al., 2011). Emissions of gaseous pollutants and aerosol particles from biomass burning significantly contribute to the tropospheric budgets on local, regional and even global scales (Andreae and Merlet, 2001; Koppmann et al., 2005; Li et al., 2007). The Northeastern Plain is one of the main sources of sulfur dioxide (SO_2), nitrogen oxides (NO_X) and carbon monoxide (CO) in China (Streets and Waldhoff, 2000). Emissions from agricultural biomass burning in this region have a significant impact on air quality, human health, and climate (Li et al., 2010).

The Sanjiang Plain is historically a contiguous wetland in northeast China. This region has experienced intensive cultivation over the past 30 years. The wetland area decreased by 41.7%, and the rice paddy area increased by 161.5% from 1986 to 2005 (Huang, 2009). During the rapid cropland reclamation period,

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prescribed burning was widely used as an effective measure to enforce the change from wetland to cropland. Currently, it is one of the most productive agricultural regions in China (Wang et al., 2011). Furthermore, this region has lower temperatures with an annual mean air temperature of 1.6–1.9 °C. The heating season starts in October and lasts until April every year. In the past, crop residues collected after harvesting were used for domestic heating in winter and for year-round cooking. Recently, with more rural families switching to cleaner fuels, the agricultural residues are increasingly burned directly in the field after harvesting. Open burning of agricultural crops also affects the fragmentized wetland vegetation. Fuel types have dramatically changed in the past 30 years. Biomass burning is a normal phenomenon in the region and high-density fires were found using MODIS data in the Heilongjiang Province (Qin et al., 2014). Few studies regarding biomass burning have been conducted in this region, and the burning amount and fuel types are still unknown.

Biomass burning has been widely investigated in China. Gaseous pollutant emissions from agricultural crop residues burning (rice, wheat and corn straws) in China, including domestic and field burning, were previously studied by Zhang et al. (2008). More detailed estimates of gaseous emissions from agricultural crop residue burning, forest and grassland burning, and biofuel combustion have been documented (Andreae and Merlet, 2001; Streets et al., 2003; Akagi et al., 2011). Additionally, the contribution of biomass burning to the total emissions of atmospheric gaseous pollutants in China, including forest and grassland burning, fuel wood consumption, and agricultural crop residue burning, was assessed by Yan et al. (2006). A few other studies regarding emission estimations from the open burning of biomass in China have been conducted (Cao et al., 2006; Li et al., 2007; Yang et al., 2008). Emissions from wetland vegetation are rarely reported because little is known about wetland burning. Little work has been completed on the emission inventories and emission allocations of gaseous pollutants from the burning of wetlands, rice paddies and dry land in the Sanjiang Plain. The emission changes resulting from land use change in this region are also unknown.

Emission inventory and emission allocation of gaseous pollutants are important for modeling and environmental impact assessments. The temporal variation of emission inventory during a period is beneficial for model analyses and forecasting. The objectives of this study were to (1) measure emission factors (EFs) of wetland vegetation and agricultural crop residue in this region, (2) discuss the relationship between land use changes and biomass burning during the last few decades, and (3) determine the emission inventory of gaseous pollutants (CO_2, CO, C_XH_Y, SO_2, and NO) from wetland, rice paddy and dry land burning in the Sanjiang Plain from 1986 to 2005. These factors could all be beneficial for a more accurate estimate of carbon and nitrogen emissions from biomass burning. It is also useful to assess the regional air quality.

2. Methodology

2.1. Study site

The study was conducted in the Sanjiang Plain in northeast China (129°11′20″E–135°05′10″E, 43°49′55″N–48°27′56″N). The Sanjiang Plain is an alluvial plain between three major rivers, i.e., the Heiron, Songhua, and Wusuli Rivers, encompassing 23 counties. The climate is a humid and sub-humid continental monsoon, with a mean annual precipitation of 500 to 650 mm and a mean annual temperature of 1.4 to 4.3 °C. Low slope gradients and inductive climate conditions make this one of the largest marshes in China. The main wetland types are depressional and riparian wetlands. The natural vegetation is wet meadow and marsh communities, with dominated wetland plants, including *Carex lasiocarpa*, *Carex pseudo-curaica*, *Phragmites australis*, *Carex meyeriana*, *Carex appendiculata*, *Calamagrostis angu-stifolia*, *Salix rosmarinifolia var brachypoda*, and *Spiraea Salicifolia* (Zhao, 1999). A dramatic change in land use occurred in this region to address an increasing population. From 1986 to 2005, the number of marshes declined from 1476 to 1037, and the total area decreased from 139×10^4 hm^2 to 84×10^4 hm^2 (Wang et al., 2011). Because of governmental policies aimed to protect and restore marshes, some dry cropland (soybean) was converted to rice land. This region experienced a special evolution from wet to dry then again to wet from 1986 to 2005. During this time, the wetland area declined by 41.7%, and the rice paddy and dry crop land increased by 161.5% and 13.8%, respectively (Fig. 1).

2.2. Experimental process and data collection

Annual pollutant emissions from biomass burning in the field can be calculated using the product of the emission factor of a particular pollutant by the total amount of biomass burning in the field, according to the expression used by Delmas et al. (1995):

$$E = EF \times M \quad (1)$$

where *E* is the amount of a particular pollutant emitted annually (g a^{-1}), *EF* is the amount of a particular emitted pollutant per unit of biomass burned in the field (g kg^{-1}), and *M* is the amount of biomass annually burned in the field (kg a^{-1}).

The *EF* values of carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), nitric oxide (NO) and hydrocarbons (C_XH_Y) were measured in the laboratory using an integrative smoke analyzer (KM-9106, England). Wetland plant and crop residue were collected in the field in October, grinded and passed through a 60-mesh sieve. Approximately 5.00 g of samples was combusted in a self-built burning device with a temperature of 480 to 500 °C. The CO_2, CO, SO_2, NO and C_XH_Y were collected by the integrative smoke analyzer (KM-9106, England). For each type of vegetation, three burning tests were conducted successively. Gaseous pollutant concentrations were recorded every 10 s using fireworks soft. The release curves were fitted by the Table Curve 2D V5.0 Trial. According to the gaseous pollutants release curves and mass balance, the EF was calculated using Eq. (2). The carbon-mass balance method has been widely used to calculate emission factors during biomass burning (Radke et al., 1998; Deng, 2006; Wang et al., 2009). Additional details on deriving emission factors from carbon mass balance can be found in Deng (2006) and Wang et al. (2009).

$$EF = M_i / M_{fuel} \quad (2)$$

where M_i is the mass of emitted species I, and M_{fuel} is the mass of the burned fuel.