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An estimation of CO_2 emission via agricultural crop residue open field burning in China from 1996 to 2013

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A B S T R A C T

The field burning of agriculture straw residue is a common method to dispose waste after harvesting seasons in China. The burning of agricultural crop residue in open field which has been given little attention up till now represents an important source of CO_2 for global warming concern. According to the CO_2 emission factors of rice, wheat, and corn straws based on laboratory measurements, the amount of CO_2 emission via agricultural crop residue open burning in China between 1996 and 2013 has been calculated. The diverse accounting methods and geographic information system (GIS) are used to map the CO_2 emission of thirty-one provinces. Identifying the spatial distribution, 5-year average variation, and contributions of CO_2 emission by three major agricultural residue open burning, it is found: (i) About 2707.34 Tg of CO_2 is emitted by agriculture residue open burning, occupies 45.09% of the total residential coal consumption from 1996 to 2013 (ii) The total emission from rice, wheat and corn straw burning are concentrated in south and northeast of China, North China and northeast of China, respectively (iii) Shandong Province contributes the largest portion of CO_2 emission, Henan, Jiangsu, Hebei and Hei Longjiang rank the second, third, forth, and fifth, respectively. From different level of CO_2 emission by agricultural crop residue open burning, we can find mitigation potential of greenhouse gas emission and give three suggestions: (i) generalizing straw returning field application (ii) improving the efficiency of straw utilization (iii) commercializing biomass energy. However, the mitigation potential, and varied policies and regulations need to be developed which are related to the local economic and environmental conditions in different China rural places.

1. Introduction

With the high-speed economic growth in the past decades, China is simultaneous existence of persisting poverty, alongside irrational energy structure and environmental degradation (Liu et al., 2012). As a vast agriculture country, China possesses a large rural population who traditionally uses bio-fuel (crop residue) as major energy source for centuries (Yan et al., 2006; Zhang et al., 2008). Along with remarkable urbanization, the consumption of non-commercial energy has recently converted to coal and natural gas in rural areas over the course of the past 30 years (Cao et al., 2005, 2006b). Not being used as domestic fuel, a large amount of agricultural crop residue was burned directly in the open field especially in grain-producing regions where are high density of population, economic developed areas, and abundant fossil fuel producing (Irfan et al., 2014; Liska et al., 2014). As a consequence, more and more environmental problems caused by energy structure transformation in rural places have emerged from intuitive. The direct burning of agriculture crop residue in the open field has been considered as an important source of atmospheric pollution by now with significant impacts on atmospheric chemistry and global climate change and with great threat to human health (Brühl et al., 2015; Pongpiachan et al., 2015; Udeigwe et al., 2015). Among these series of atmospheric pollutants, CO_2 emission which primarily leads to global warming was mostly focused on fossil fuel combustion by past (Streets et al., 2001). With hundreds millions of agricultural crop residue burned each year in China (Kung et al., 2015; Zhang et al., 2015a, 2015b), it can't be ignored

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that agriculture straw combustion has already become one of the important sources of CO_2 emission (Li et al., 2007; Rakowski, 2015; Zhang et al., 2011) (Table 1).

There are limited studies on CO_2 emissions from major agricultural crop residues burning in the open field for a long period at province level that have been conducted. De Zárate et al. (2000) use the results of laboratory chamber combustion and a field burning experiment to estimate atmospheric emission by cereal waste burning in Spain (De Zárate et al., 2000). Nguyen et al. (1994) collected atmospheric samples during rice straw burning at four different locations in Viet-Nam in South East Asia for two years to measured CO, and CH_4 emissions (Nguyen et al., 1994). Dhammapala et al. (2006) performed wheat and bluegrass stubble burn experiments at the US EPA open burning test chamber and measured trace gas emissions (Dhammapala et al., 2006). Streets et al. (2003) performed biomass from grassland and savanna burn experiment to measure several gaseous pollutants over the Indian and East Asian regions and used geographic information system (GIS) to supply several useful information on a broader scale (Streets et al., 2003). In China, Zhang et al. (2013) used a self-designed combustion simulation system to measure carbonaceous pollutants emissions from rice straw and sugarcane leaves burning in the Pearl River Delta Region (Zhang et al., 2013). Zhang et al. (2008) used a burning stove and aerosol chamber to investigate emission factor and emission inventory (CO_2, CO, NO, NO_2 and NOx) of agricultural crop residue combustion. Zhang et al. (2011) made a research on particle size distribution and polycyclic aromatic hydrocarbons (PAHs) emissions from agricultural crop residue combustion. Li et al. (2007) made a measurement to determine particulate emissions and trace gas emissions from wheat straw and maize open combustion. However, although Zhang et al. (2008) has made investigation on CO_2 emission from agricultural crop residue combustion, little work has been done on CO_2 emission inventories and CO_2 emission allocations for a long period of time at province-level from agricultural crop residue burning in the open field in China area.

In this work, we use the CO_2 emission factors which are the results of self-built laboratory chamber combustion from three major agricultural residue of rice, wheat, corn straw to measure the emission inventory of CO_2 via agricultural crop residue open burning from 1996 to 2013 in China. The emission inventory and emission allocation using geographic information system (GIS) (Dalvi et al., 2006) of CO_2 from the open burning of rice, wheat and corn straws are discussed. By identifying the spatial distribution, 5-year average variation, and contributions of CO_2 emission by three major agricultural residue open burning, we can generate CO_2 emission concentration area, CO_2 emission variation tendency. Moreover, this paper will provide theoretical basis to formulate policies and regulations by policy makers.

2. Research domain and methods

The laboratory simulation is the common way to investigate biomass burning. In this paper, using the results of self-built laboratory chamber combustion from three major agricultural residue of rice, wheat, corn straw, the CO_2 emission inventory has been calculated applying data from China Agriculture Statistical Yearbook. In addition using geographic information system, the CO_2 emission allocation has been mapped.

2.1. Research scope

Because the complicacy and the diversity of statistical, there is an inherent problem of data availability in agriculture straw statistics in China. It is the real fact that the data associated with agriculture straw is collected and compiled by multiple sources and through different channels. Due to the different statistical standards and methods, there are substantial differences in the data. To ensure consistency in data use and statistics, we mainly relied on crop out put data from the China Agriculture Statistical Annual Report which is the official data sources by national bureau of statistics (Zhang et al., 2010). The time span of the research is from 1996 to 2013, as long as 18 years. The region of the research is thirty-one provinces (municipality, autonomous region) in China, among which the agriculture straw yield of Hong Kong, Macao and Taiwan is not taken into account temporarily.

2.2. Method of calculation

There is little work that has been carried out on the emission inventory of agriculture straw (rice, wheat and corn straws) combustion. Emission factor is the important parameter to represent the symbol of gaseous pollutant by crop residue combustion and also the basic data to establish the air pollutant emission inventory. Although default emission factors of straw have been provided by IPCC (Houghton et al., 1996), different utilization patterns (various combustion chamber) in China make it difficult to estimate reasonable values for combustion efficiency. Therefore, we tried to

Table 1
CO_2 emission from burning of rice, wheat, and corn straw from 1996 to 2013 in China (*10^4 t).

year	Rice straw burned	Wheat straw burned	Corn straw burned	Total CO_2 emitted
1996	2930.14	3226.71	4950.80	13590.94
1997	3080.75	3478.07	5547.38	14854.31
1998	3159.68	3861.61	4530.24	14231.15
1999	3139.95	3393.65	5766.13	15045.58
2000	3112.26	3602.69	5524.55	15044.57
2001	2907.69	3101.54	4557.12	12881.55
2002	2732.32	2874.24	4939.30	12870.78
2003	2668.38	2738.77	5185.50	12919.72
2004	2421.93	2624.43	4957.44	12258.88
2005	2692.13	2794.24	5569.57	13509.43
2006	2706.18	2987.11	5966.26	14321.45
2007	2751.98	3207.34	6251.52	15060.65
2008	2780.55	3395.26	6527.28	15723.89
2009	2856.26	3492.75	7096.32	16653.52
2010	2908.37	3560.72	7011.21	16693.27
2011	2914.37	3566.42	7552.17	17389.33
2012	2999.39	3637.34	8236.98	18430.98
2013	3038.21	3747.68	8728.65	19253.84

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