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Climate Change Effect from Black Carbon Emission: Open Burning of Corn Residues in Thailand

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***Abstract*—**This study focuses on emission of black carbon (BC) from field open burning of corn residues. Real-time BC concentration was measured by Micro Aethalometer from field burning and simulated open burning in a chamber (SOC) experiments. The average concentration of BC was 1.18±0.47 mg/m^3 in the field and 0.89±0.63 mg/m^3 in the SOC. The deduced emission factor from field experiments was 0.50±0.20 g_{BC}/kg_{dm}, and 0.56±0.33 g_{BC}/kg_{dm} from SOC experiment, which are in good agreement with other studies. In 2007, the total burned area of corn crop was 8,000 ha, resulting in an emission load of BC 20 ton corresponding to 44.5 million kg CO_2 equivalent. Therefore, the control of open burning in corn field represents a significant global warming reduction option.

***Keywords*—**Black carbon, corn field residues, global warming, mitigation option

I. Introduction

BLACK carbon is estimated to be the second most potent greenhouse warming agent after carbon dioxide. The BC is recently more awareness because of its potential in warming effect that is increased when mixed with other particles, reduces the earth's albedo at high layer in the atmosphere, absorbs more energy by trapping and retaining energy reflected off of clouds below, and accelerates melting of snow and ice three times that of CO_2. However, BC is airborne for only one to several weeks, which is shorter than CO_2 that lasting for 100-120 years. Major sources of the BC are burning of fossil fuels, biofuels, and biomass. Open burning of agricultural residues after harvesting is a significant source that release BC to the atmosphere. Thailand is one of major corn exporters in the world after America, Argentina, and France. After harvesting, residues of corn are not utilized and usually burned in the field. However, emission load of BC from open burning of corn residues is still unavailable because there is no emission factor and also amount of corn residues specific to corn residues in Thailand. The available EF_{BC} is the studies of open burning of global agricultural residues in the field, burning of crop waste in household stoves in China, and open burning of maize stover in China [1]-[3]. Therefore, this study aims to estimate emission factor and emission load of BC specific to open burning of corn residues in Thailand to consider global warming effect and also mitigation options.

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II. Methodology

A. Studied Area

The studied area was located at latitude 101.51°E longitude 14.52°N, Pakchong district, Nakhonratchasima province, northeastern part of Thailand (Fig. 1). There are two main types of corn in this area, which are sweet corn for human food and corn for animal food. Type of the biomass that considered in this study is corn cultivated for industrial animal food because residues of this corn type are usually burned in the field after harvesting. Farmers planted corn once a year by relying water resource on rain water. The corn type was 919 planted by machine in July and harvested manually in January. Normally, duration of plantation to harvesting was 120 days but this crop was 180 days to gain value from dry product.

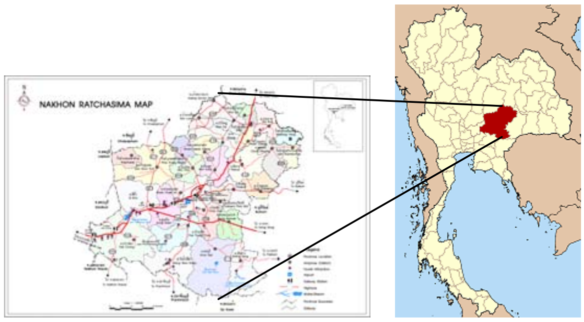

Fig. 1 Studied site located in Nakhon Ratchasima province

B. Corn Residue

The remaining residues in the corn field after harvesting consisted of leaves, stem, and envelope (Fig. 2). Production of corn was harvested manually so corn seed and cob were moved out of the field (Fig. 3). After harvesting, these residues were bent down and burned immediately because they were dried enough for ignition. Amount of biomass was considered as biomass load (BL), which was carried out by collecting biomass in 2 m ×2 m randomly for four samples at the studied site. We measured wet weight of corn residues at the field. Then the samples were collected back to the JGSEE laboratory to consider moisture content. Then calculate dry mass of corn residues per area to obtain biomass load (BL,

g_{dm}/m^2). The collected samples were used as a fuel for simulating open burning experiment in the chamber.

Fig. 2 Biomass remained in the field

Fig. 3 Biomass moved out of the field

C. Field Open Burning Measurement

A prescribed burn experiment was conducted at the corn field. Area of the prescribed burn was 7 m × 8 m. The burning was prepared and conducted by traditional way of farmer (Fig. 4- Fig. 5). Farmer prepared the biomass by bending the residues down and igniting the fire at an upwind point. The measurement was conducted to monitor BC concentration in the ambient air by measuring before burning and monitor emission during burning by measuring in the plume. The black carbon concentration was measured real-time by Micro Aethalometer (model AE51, Magee Scientific, USA) at flow rate 5 ml/min. The emission of BC concentration from open burning of corn residues was measured by installing the Micro Aethalometer at 1 m height ground level downwind and moving to keep inlet of the instruments in the plume all the time.

Fig. 4 Biomass prepared for open burning

Fig. 5 Open burning of corn residues in the field

After finish burning, ash and unburned residues were collected back and analyzed for moisture content at the laboratory to consider dry mass for calculating combustion efficiency.

D. Simulate Open Burning Measurement in the Chamber

Experiments of measuring BC emission from corn residues burning were carried out in the chamber that was designed for simulating open burning. The design of this chamber was to reduce surrounding effects, especially variation of wind direction and speed in the field. Moreover, we can know the exact amount of fuel before and after burning. The chamber consists of two main parts, which are combustion zone size 1 m × 1 m × 1 m at the bottom part and a 2.8 m height with 25 cm × 25 cm stack at the upper part (Fig. 6). The upper part and three sides of the combustion zone were closed. The inlet air was from an open side of the combustion zone at the bottom part. There was no air inlet by force in order to perform open burning in calm wind condition in the field.

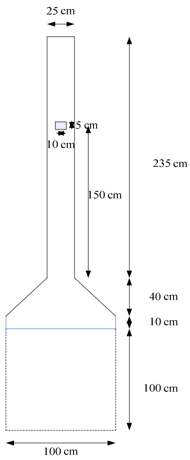

Fig. 6 Simulated Open Burning Chamber (SOC)

The Micro Aethalometer was installed the same as field experiment by positioning in front of the opened side of the chamber at ground level 1 m height. The inlet of the instrument was kept inside the plume all the burned period. Seven experiments were conducted to measure BC emission from simulate open burning of corn residues in the chamber. Size of the corn residues sample in each experiment was 515 ± 82 g to represent for the same amount of biomass load in the field (BL 526 ± 91 g/m^2).

E. Calculation of Emission Factor and Emission Load

Average maximum BC concentration results and burning rate were calculated to be emission factor (EF_{BC}) in unit of g_{BC}/kg_{dm}. The average maximum concentration was average of the concentration that above average concentration of BC at the ambient air. The emission load was estimated by using emission factor and amount of burned corn residues in the field. The total burned amount of corn residues was obtained from results of biomass load and fraction burned in this study, national statistical data of harvested area from Office of Agricultural Economic Thailand and percentage of burned area from literature review[4], [5].

The average maximum BC concentration results and burning rate were calculated to be emission factor (EF_{BC}) in unit of $g_{BC}/kg_{dry\ mass}$ by the following equation.

$$EF = C_{BC}/BR \quad (1)$$

where *EF* is emission factor (g/kg), C_{BC} is average maximum concentration of black carbon (mg/m^3), *BR* = burning rate (g/s). The measurement concentration of BC that was lower than average ambient air did not take into account.

The annual emission load (*E*) was estimated by multiplying emission factor (*EF*) with the annual amount of burned corn residues (*M*) in the field.

$$E = M \times EF \quad (2)$$

The total burned amount of corn residues was obtained from results of biomass load (BL, g/m^2), combustion efficiency
(CE, %), fraction burned (FB, %) in this study, and burned area (A, m^2) from secondary data.

$$M = BL \times FB \times CE \times A \quad (3)$$

FB is fraction of corn residues left in the field after utilization (%), *CE* is combustion efficiency or fraction of biomass burned in the field (%), which can be calculated by

$$CE = 100 \times (B_{before}-B_{after})/B_{before} \quad (4)$$

where B_{before} is amount of biomass before burning (g/m^2) and B_{after} is amount of unburned biomass after burning (g/m^2). Burned area (*A*) of corn field was estimated by national statistic data of harvested area and percentage of burned area from literature review [4], [5].

$$A = A_H \times \%A_B \quad (5)$$

where A_H is harvested area (m^2) and $\%A_B$ is percentage of burned area (%). From the result of these calculations, the annual emission load of open burning in corn field was estimated.

III. Results and Discussion

A. Biomass Load of Corn Residues

Considered corn residues in this study consist of major burned part, which are leaves, stem, and envelope that contain moisture for 6.11%, 7.51%, and 5.22%, respectively. The moisture content of corn residues was low because the farmer let the product dried before harvesting. However, it is the same as another study in Thailand that maize stalk was 8.42% moisture content [6]. Biomass load of these corn residues is 526±91 g_{dm}/m^2, which is lower than the published data of other countries [7], [8] presented in TABLE I.

TABLE I
BIOMASS LOAD RESULT

Biomass type	BL (g_{dm}/m^2)	Country	Sources
Corn residues	526±91	Thailand	this study
	890	USA	[7]
	1,000	Not specify	[8]
	593-1,186	USA	[9]

Note: dm = dry matter

From TABLE I, the available published data is mostly in USA, which presented double higher amount of corn residues when compare with Thailand.

B. Results of Open Burning Measurement in the Field and in the Chamber

The average concentration of BC was 1.18±0.47 mg/m^3 measured from open burning in the field and 0.89±0.63 mg/m^3 measured in the SOC. Results from both burning in the field and in the SOC agreed well. The deduced emission factor from field experiments was 0.50±0.20 g/kg_{dm} from field experiment, and 0.56±0.33 g/kg_{dm} from SOC experiment, which are in good agreement with other studies [1]-[3]. Comparison of results in this study and literature review is presented in TABLE II.

TABLE II
EMISSION FACTOR OF BC FROM OPEN BURNING OF CORN RESIDUES

Fuel type	EF_{BC} (g_{BC}/kg_{dm})	Burning	Country	Sources
Corn residues	0.50±0.20	Field	Thailand	This study
	0.56±0.33	Chamber	Thailand	This study
	0.21-0.68	Stove	China, Chongqing	[2]
	0.16±0.10	Stove	China, Shandong	[2]
Agricultural residues	0.69±0.13	Field	Not Specify	[1]
	1.38±0.70	Stove	China	[3]

The literature of BC emission from burning of corn residues is limited; especially open burning in the field. Therefore, the results are compared with burning of corn residues in the stove for cooking in China. The emission inventory of BC from the open burning in agricultural field is usually based on [1], which presents EF_{BC} from best guess.

C. Emission Load

Emission load of BC from open burning of corn residues are considered based on national data in 2007. Burned area of the con field was 15% [4] of the harvested area 54,226 ha from national agricultural statistic data [5]. Total burned area of corn crop was 8,134 ha, which contains corn residues 36.16 G·g. Combustion efficiency of corn residues is 85%±13%, resulting in an emission load of BC 20.25 ton. The estimates of global warming potential of BC have large uncertainties by $GWP_{BC,100}$ ranges from 210 to 1500, and $GWP_{BC,20}$ ranges from 690 to 4,700. Lifetime of of the BC in the atmosphere is 1-10 year so global warming potential (GWP) 20 years is selected to consider global warming effect in this study. The central value of $GWP_{BC,\ 20}$ is about 2,200; that is during 20 years after emission from corn field, 1 kg of BC produces as much global warming forcing as 2,200 kg of CO_2 [10]. Annual BC released from corn field corresponding to 44.5 G·g CO_2 equivalent.

IV. Conclusion

Corn is a major economic crop to feed industrial animal food so a large amount of corn residues are burned after harvesting and consequently a large amount of gases and aerosols are released into the atmosphere. Black carbon emission from burning in the corn field is a major air pollutant that enhances global warming effect. However, the study of BC released from corn field burning is limited. Therefore, this study has estimated black carbon emission factor and emission load from open burning of corn field to consider global warming effect and mitigation options. Emission factor is 0.56±0.32 g_{BC}/kg_{dm}. It means that burning of 1 kg corn residues emitting 0.56 g_{BC} into the atmosphere. In 2007, total amount of corn residues burned was 36.16 G·g, which generated 20.25 ton BC equivalence to global warming effect of releasing 44.5 G·g CO_2 into the air. To reduce the global warming effect from this matter, the farmer should realize how large BC emission load has been generated from their burning activity and enhance global warming effect so they should collect corn residues to utilize or plough them back into the soil instead of burning.

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