

Assessment of climate pollutant emissions from crop residues open burning in Indonesia

Ade Andini^{1,2}, Sebastien Bonnet^{1,2,*}, Patrick Rousset^{1,2,3}

¹The Joint Graduate School of Energy and Environment – King Mongkut's University of Technology Thonburi (JGSEE – KMUTT), Bangkok, Thailand.

²Center for Energy Technology and Environment, Ministry of Education, Bangkok, Thailand.

³CIRAD – Agricultural Research for Development Biomass, Wood, Energy, Bioproducts team Internal Research Unit – BioWooEB, Montpellier, France.

Abstract:

Indonesia is an agricultural country. The practice of open burning is commonly followed by farmers to remove residues from the field. The main crops subject to open burning include, rice, corn, cassava and sugarcane. It is estimated that about 45 million tonnes of such residues are open burned on an annual basis. In order to estimate the contribution of these practices on air pollution, suitable pollutant and crop specific emission factors were retrieved from the literature. Based on this data, it was found that on annual basis crop residues open burning in Indonesia contributes 49,671Gg CO₂, 4,675Gg CO, 243Gg CH₄, 85Gg NO_x, 3Gg N₂O, 40Gg SO₂, 151Gg NMVOC, 21Gg EC and 77Gg OC. On average, CO₂ and CO emissions were found to dominate the overall emissions with 90% and 8% respectively. The remaining 2% are contributed by all other pollutants. Based on the climate forcing contribution of these emissions, it was estimated that crop residues open burning in Indonesia contributes 14% of the GWP of global crop residues open burning.

Keywords: Crop residues; Open burning; Climate pollutants; Indonesia

*Corresponding author: E-mail address: sebastien_b@jgsee.kmutt.ac.th

1. Introduction

Indonesia is a major agricultural producer in the world. FAO (2015) revealed that 30 % of its land is dedicated to agricultural production. The major food crops produced in Indonesia based on harvested area include, rice, corn, cassava, soybean and peanut. One of the major issues associated to such activities is the burning of crop residues in the field following harvest. Open burning practice mostly occurs during the dry season. It is responsible for a number of adverse impacts, through the emissions of greenhouse gases (GHG) and particulate matter, including, air pollution, climate change (global warming), health impacts (respiratory problems) and economic impacts (including bilateral relationships with neighboring countries) (Gadde et al., 2009; Mahmud, 2013; Permadi and Oanh, 2013). In this study, the contribution of major crop residues open burning on climate pollutant emissions in Indonesia was assessed.

2. Material and methods

In order to evaluate climate pollutant emissions from crop residues open burning, the amount of residues subject to open burning in Indonesia was retrieved from a previous study by Andini et al. (2016). Based on this information, the emissions of air pollutants were assessed for four major crops produced in the country that are, rice, cassava, corn and sugarcane. The calculations were performed based on Eq. (1) as follows:

$$E_a = R \times \eta \times EF_a \quad (1)$$

Where, for a particular crop residue, E_a = Emission of 'a' in Gg/yr; η = Fraction of biomass oxidized during combustion. EF = Emission factor of 'a' in g/kg of dry crop residues. R = Quantity of crop residues subject to open burning in Tg/yr (for a specific crop). a = pollutant species.

Based on Eq. (1), data related to two main parameters needed to be collected that are the fraction of biomass oxidized and pollutant specific emissions factors. With regard to the fraction of biomass

oxidized during combustion, specific values were collected from a study by Turn et al. (1997). Concerning pollutant specific emissions factors, crop specific data were retrieved from an extensive literature review. The process to select adequate emission factors consisted in identifying values that are specific to the crops considered in this study and that relate to open burning activities in Indonesia as first priority, and, if not available, to the region. In the absence of information for Asia, default values from other published sources were be considered, mostly from Andreae and Merlet (2001). Details of the emissions factor values selected for this assessment and their sources are shown in Table 1.

Table 1 Crop pollutant specific emission factors

Emission Factors (g kg ⁻¹)	CO ₂	CO	CH ₄	NO _x	N ₂ O	NH ₃	SO ₂	NMVOC	PM ₁₀	PM _{2.5}	EC	OC
Rice Straw	1,216 ^b	179.9 ^b	9.59 ^b	3.10 ^c	0.07 ^a	4.10 ^b	2.00 ^d	4.00 ^e	9.4 ^f	4.2 ^b	0.51 ^f	2.99 ^f
Cassava	1,130 ^j	86.30 ^j	4.56 ^j	0.70 ^j	0.07 ^a	1.30 ^a	0.216 ^j	4.35 ^j	8.05 ^j	3.88 ^k	0.47 ^k	0.91 ^k
Corn	2,327.14 ^g	80.3 ^h	3.4 ^h	3.7 ^h	0.07 ^a	1.6 ^h	0.44 ⁱ	4.40 ^h	4.26 ^h	4.13 ^h	0.95 ^g	2.25 ^g
Sugarcane	1,130 ^j	34.66 ^h	0.41 ^h	2.63 ^h	0.07 ^a	0.95 ^h	0.216 ^j	2.18 ^h	3.99 ^h	3.77 ^h	0.77 ^l	0.91 ^k

Note: ^aAndreae and Merlet (2001): Default EFs for several types of biomass burning. ^bChristian et al. (2003): Specific EFs for rice straw open burning in Indonesia. ^cKadam et al. (2000): Specific EFs for rice straw open burning in California. ^dJenkins and Bhatnagar (1991): Specific EFs for rice straw open burning. ^eUS EPA (1992): EFs for rice straw from the AP-42 database developed by the USEPA. ^fOanh et al. (2010): Specific EFs for rice straw open burning in Thailand. ^gCao et al. (2008): Specific EFs for corn residues based on combustion tower experiment in China. ^hDennis et al. (2002): Specific EFs for corn and sugarcane open burning in Texas. ⁱLi et al. (2007): Specific EFs for corn stover open burning in China. ^jZhang et al. (2000): Default EFs for crop residues open burning in China. ^kReddy and Venkataraman (2002): Default EFs for crop residues open burning in India. ^lPenner et al. (1996): Specific EFs for sugarcane at developing areas.

3. Results and discussion

3.1 Emissions from crop residues open burning

Based on Eq. (1), the annual emissions of climate pollutants were estimated. The results are detailed in Table 2. The annual amount of crop residues subject to open burning and fraction of biomass oxidized during combustion for each type of crop are also indicated. It is observed that on an annual basis, about 45 Tg of rice, corn, cassava and sugarcane residues are open burned. This represents about 21% of the total amount of crop residues produced nationwide. In terms of emissions, the above results indicate that open burning of residues for all crops considered contribute mostly to CO₂ emissions in the range 85-96%, followed by CO in the range 3-13%. The remaining fraction is contributed by all other pollutants, including, CH₄, NO_x, N₂O, SO₂, NMVOC, EC (elemental carbon) and OC (organic carbon). Depending on the crop considered, the contribution to climate pollutant emissions varies. The open burning of rice straw is observed to contribute the largest emissions. Although sugarcane emissions appear to be the lowest and much less significant as compared to rice corn and cassava, as reported by Andini et al. (2016), it is the crop with the highest proportion of crop residues subject to open burning, i.e.76%. As the government of Indonesia is considering promoting biofuels such as ethanol for transport in the near future, an expansion of sugarcane plantations is expected to meet future policy targets. This could lead to much larger emissions of climate pollutants if open burning practices are not controlled.

3.2 Contribution to global warming potential

The Global Warming Potential (GWP) is expressed in the form of CO_{2eq}. It is divided into warming agents i.e. CO, CH₄, NO_x, N₂O, NMVOC and EC with positive forcing; and cooling agents i.e. SO₂ and OC with negative forcing. As per the IPCC 2006 guidelines, CO₂ was considered as carbon neutral and thus not accounted for in the assessment. Table 3 shows that in 2014, Indonesia

contributed about 13 Tg CO₂-eq over a 100 year-time horizon. Based on GFED 4 data, this represents about 14% of the GWP of global crop residues open burning.

Table 2 Annual emissions of air pollutants from crop residues open burning in Indonesia

Crop types	R ^a	η ^b	Emissions (Gg/year)								
			CO ₂	CO	CH ₄	NO _x	N ₂ O	SO ₂	NMVOG	EC	OC
Rice Straw	19.3	0.89	20,874.55	3,088.27	164.63	53.22	1.2	34.33	68.67	8.75	51.33
Cassava	18.5	0.68	14,198.31	1,084.35	57.3	8.8	0.88	2.71	54.66	5.91	11.43
Corn	6.7	0.92	14,276.12	492.61	20.86	22.7	0.43	2.7	26.99	5.83	13.8
Sugarcane	0.4	0.68	322.45	9.89	0.12	0.75	0.02	0.06	0.62	0.22	0.26

Note: R refers to the quantity of crop residues open burned (Tg/yr); η refers to the fraction of biomass oxidized during combustion. Sources: ^aAndini et al., (2016); ^bTurn et al., (1997).

Table 3 Contribution of Indonesia's crop residues open burning to the global agricultural open burning GWP

Global warming and cooling agents	Indonesia (this study) Gg CO ₂ -eq (100 yr)	Global estimates Gg CO ₂ -eq (100 yr)
CO, CH ₄ , NO _x , N ₂ O, NMVOG and EC	25,438.59	192,086.00
SO ₂ and OC	-12,160.63	-94,728
Total net GWP	13,277.97	97,358

^aGlobal emission for base year of 2014 were retrieved from GFED 4, <http://www.geo.vu.nl/~gwerf/GFED/GFED4/tables/>

4. Conclusions

In Indonesia, emissions from crop residues open burning were found to be dominated by CO₂ and CO in the range 85-96% and 3-13%, respectively. The remaining fraction (1-3%) was found to be contributed by all other pollutants. It is this fraction comprised of major climate positive forcing pollutants (in particular EC and CH₄) that leads Indonesia to contribute about 14% of the GWP of global crop residues open burning (over a 100 year-time horizon).

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