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Assessment of Biomass Loss and Air Pollution Caused by Pre-Harvest Sugarcane Burning Using the Closed Loop Combustion System Model

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Abstract

This research aimed to analyse biomass loss and total pollution due to pre-harvest burning of sugarcane by using the Closed Loop Combustion System Model for investigating its effects on the environment in order to support non-sugarcane burning promotion. The results showed that 16.61 tons/ha of sugarcane leaf were burned, or 16.65% of sugarcane yield. Total heat energy loss was 292,712 MJ/ha which was estimated to equal electrical power 6,118 kW-h/ha. The plant nutrient contents in sugarcane leaf and ash were not found to be significantly different. Nevertheless, an economic analysis indicated that the employment of a practice that does not burn sugarcane might reduce somewhat the cost of major fertilizer (NPK) inputs as compared to pre-harvest sugarcane burning. The amount of the pollutants CO, NO_2 SO_2 and CO_2 in the air caused by burning 100 g of dried sugarcane leaf in the Closed Loop Combustion System Model was 4,406, 43.7, 104 and 154,055 mg, respectively, and the weight by area was 731, 7.26, 17.3 and 25,592 kg/ha, respectively. This practice would likely lead the pollutant concentrations increasing in our atmosphere, which could cause worsened allergies or death for humans and harm to other living organisms such as animals and food crops. Moreover, the CO_2 released by burning sugarcane contributes to global warming.

Keywords: Sugarcane burning; Air pollution; Biomass loss; Closed loop combustion

1. Introduction

Thailand is the world's 4th largest sugarcane producer and also the 2nd largest sugar exporter. Sugarcane is essential raw material for sugar industries, so it is important for economic and social development (Office of the Cane and Sugar Board, 2014). Due to the sugarcane industry's trend to expand every year, sugarcane farmers grow more sugarcane and harvest manually in most areas. For convenience, sugarcane farmers choose to burn sugarcane before harvesting (Tedgaw, 2011; Jaithan, 2013). In Thailand, the percentages of burned sugarcane in the production seasons 2011/2012, 2012/2013, 2013/2014, 2014/2015 and 2015/2016 are 65.53%, 65.79%, 63.38%, 65.17% and 64.80%, respectively (Office of the Cane and Sugar Board, 2016). This burning prior to harvesting causes air pollution in the forms of smoke, toxic gas, dust, and particles in the air (Coelho *et al.*, 2008; De Andrade *et al.,* 2010; Hiscox *et al.*, 2015). This smoke and soot may reach urban centers and introduce numerous chemical compounds into the atmosphere including carbon monoxide, sulfur dioxide, nitrogen dioxide and carbon dioxide beside the biomass burning is emerged into the composition of aerosol (Allen *et al.,* 2004; Lara *et al.,* 2005; Scaramboni *et al.,* 2015) including soil degeneration. These problems lead sugarcane farmers to use more chemical fertilizer that increases the spending on fertilizing and weeding (Boonthum *et al.*, 1993; Lachitavong, 2006). Moreover, it lowers the quality of sugarcane by reducing the amount of Commercial Cane Sugar (CCS) (Boonthum *et al.,* 1997). These problems affect the environment, economic and social unsustainability of the country. The goal of this research may provide the scientific data to support the policies and management approaches that refrain from pre-harvest sugar burning in order to improve the environment with an upward trend every year and to enhance the efficiency of sugarcane management systems permanently.

2. Materials and Methods

2.1 Apparatus

The Closed Loop Combustion System Model (CLCSM) was created for burning sugarcane leaf samples. It was cylindrical with a diameter of 50 cm and a height of 70 cm; with a rectangular opening of 10×15 cm at the bottom to insert samples and remove the ash (Figure 1). An air input pipe was also installed at the bottom of the model on the side of the cylinder; it was 12 cm in diameter and 100 cm long, with a hole drilled in the middle of the pipe to insert an air volumetric meter (Testo 480). The pipe connects to an air controller (10 cm diameter fan) that controls the flow volume of air into the system. An air output pipe was installed on the top; it is also 12 cm in diameter and 100 cm long with a hole drilled in the middle of the pipe to install the air quality meter (Testo350).

2.2 Site sampling

The sugarcane leaf samples were collected from Kudpladuk Subdistrict, Chuen Chom District, Maha Sarakham Province, Thailand. The collection period was from December 2016 to January 2017 during the sugarcane harvesting season.

2.3 Quantification of burned sugarcane leaf in the plot

The sugarcane cultivated area was 48 m^2, divided into eight plots. Four plots of sugarcane were freshly harvested with the leaves and weighed, but the other four plots were burned prior to harvesting and then weighed. The weights of all burned sugarcane leaf and its ash were used to calculate the amount of heat energy loss and nutrient loss that could be attributed to the biomass burning.

2.4 Analysis of heat energy of dried sugarcane leaf

The heat energy of sugarcane leaf samples was determined using the Bomb Calorimeter methods (Standard ASTM Test Methods).

2.5 Analysis of the nutrient loss caused by sugarcane burning

The dried sugarcane leaf was analyzed to obtain the nutrient contents including N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn and B (Attanandana and Chanchareonsook, 1999). After burning, ash was analyzed in order to find the nutrient contents of plants as mention previously.

2.6 Analysis of pollutant from burning dried sugarcane leaf in the CLCSM

Dried sugarcane leaf samples of 100 g, resized to approximately 5-10 cm, were inserted

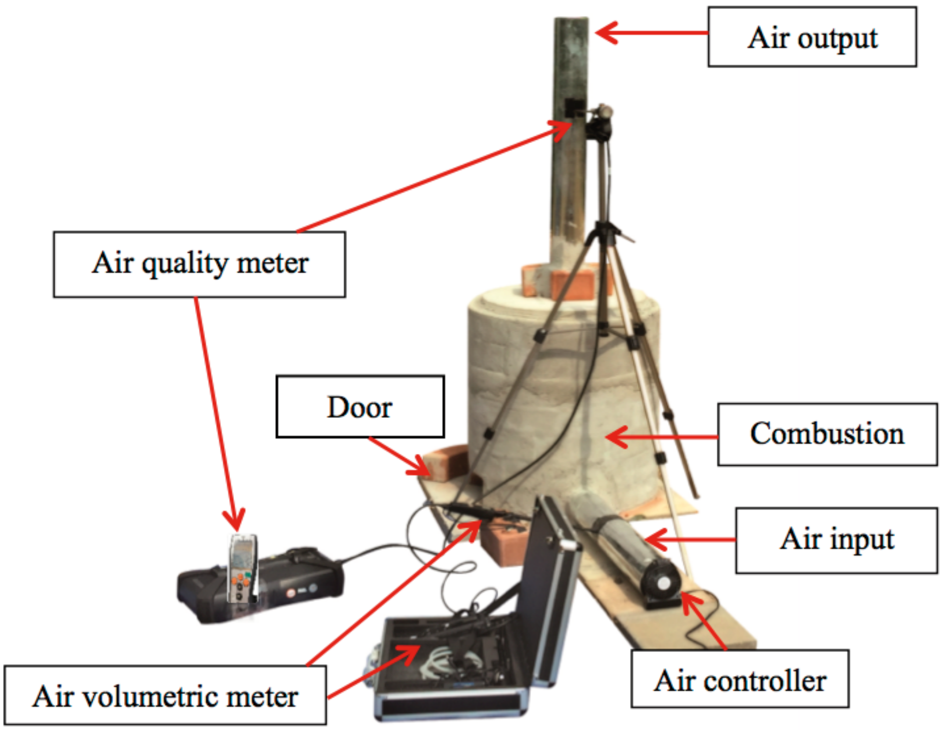

Figure 1. Closed Loop Combustion Model

into the combustion cylinder through the door and were burned while the door was closed. The toxic gases including CO, NO_2 SO_2 and CO_2 were measured by the Testo 350 meter (Figure 1) (United States Environmental Protection Agency, 2002). The air volume was controlled by a fan and measured by the air volumetric meter; it was found to be 1.42 m^3/min. The temperature at the air quality measuring point was 104-373°C and the oxygen 0.81-9.14% was done for burning.

3. Results and Discussion

3.1 The amount of burned sugarcane leaf and heat energy loss

The total amount of burned sugarcane leaf in the plots in ton/ha, to determine the total loss of heat energy, is shown in Table 1. The total burned sugarcane leaf was 16.61 ton/ha or 16.65% of sugarcane yield, whereas the weight of ash was 2.19 ton/ha, which was estimated by using the CLCSM. The total heat energy loss was 69,913,706 Kcal/ha or 292,712 MJ/ha, which was estimated to be 6,118 kW-h/ha. Moreover, this was compared with the amount of sugarcane leaf in the crop year 2015/16 for the whole country, which was 94,047,041 tons (Office of the Cane and Sugar Board, 2013), with 64.8% of burned sugarcane, so the amount of sugarcane leaf was burned 10,146,923 tons, making the heat energy loss 1.79×10^{11} MJ, which was estimated electrical power of 9,933 GW-h and crude oil equivalent of 4,245 ktoe, which were similar to the report of Department of Alternative Energy Development and Efficiency (2013). Therefore, the results revealed that sugarcane leaf could be used to save energy if used as an alternative energy source to fossil fuels.

3.2 Nutrient loss caused by sugarcane burning

Results of the analysis showed that the sugarcane leaf contained more plant nutrients than the ash did. The amount of nutrient loss (kg/ha) is shown in Table 3. The highest losses were total N and K with reductions of 59.9 and 57.2 kg/ha, respectively. In addition, the amount of ash blown away by the wind while burning sugarcane also increased the biomass loss. Furthermore, potassium was proposed as a tracer of biomass burning because it is ubiquitous in the cytoplasm of plants (Scaramboni *et al.,* 2015). Although the plant nutrient contents in the sugarcane leaf and ash were not significantly different, (P-Value > 0.05) but the economic analysis indicated that the practice that does not burn sugarcane might reduce somewhat the cost of the major fertilizer (NPK) inputs compared to the pre-harvest sugarcane burning method (Boonthum *et al.,* 1993; Sawanna,2006).

Table 1. The amount of burned sugarcane leaf in the plot, and heat energy loss

Burned sugarcane leaf	Heat energy			Electricity
(ton/ha)	(Kcal/g)	(Kcal/ha)	(MJ/ha)	(kW-h/ ha)
16.61±0.68	4.2085	69,913,706	292,712	6,118

Table 2. The plant nutrient loss caused by sugarcane burning

Plant nutrients	Total (kg/ha)		Loss (kg/ ha)
	Dried leaf	Ash	
Total N (%)	61.4	1.52	59.9
Total P (%)	4.82	4.14	0.68
Total K (%)	78.9	21.7	57.2
Total Ca (%)	43.4	40.3	3.12
Total S (%)	9.05	8.90	0.15
Total Cu (mg/kg)	0.35	0.14	0.22
Total B (mg/kg)	0.14	0.08	0.06

3.3 The amount of pollutants in the air caused by sugarcane leaf burning

The amount of pollutants released by burning 100 g of dried sugarcane leaf in the CLCSM is shown in Table 2. The quality of air at the detecting point of the model was contaminated with 823, 12.6, 19.4 and 40,181.48 ppm of CO, NO_2, SO_2 and CO_2, respectively. These values were calculated to be 4,406, 43.7, 104 and 154,055 mg, respectively, and were weighted by area to be 731, 7.26, 17.3 and 25,592 kg/ha, respectively. This shows that if this burning practice continues, these toxic gases will continue to accumulate in the atmosphere, as shown in Table 3, causing environmental devastation. These pollutants can cause allergies or death for humans and also can harm other living organisms such as animals and food crops. Furthermore, this research can be imply that other combustion processes will always contribution to the increasing of air pollutants. SO_2 is especially toxic and affects the respiratory system and the function of the lungs, and causes eye irritation (Schleisinger, 1999). Inflammation of the respiratory tract causes coughing and mucus secretion, aggravates asthma and chronic bronchitis, and makes people more prone to infections of the respiratory tract. When SO_2 combines with water, it forms sulfuric acid; this is the main component of acid rain which is a cause of deforestation (WHO, 2016). In addition, severe poisoning by carbon monoxide often results in lasting damage to the central nervous system (CNS) that might be delayed, progressive, irreversible, and lethal (Maynard and Waller, 1999; WHO, 2016). While there has not been sufficient evidence of NO_2 toxicity in epidemiological studies, it is at least partially responsible for observed health effects in urban pollution mixtures (Ackerman-Liebrich and Rapp, 1999). Moreover, CO_2 released into the atmosphere is the major cause of global warming and can remain in the atmosphere for 20 to 500 years (Intergovernmental Panel on Climate Change, 2007 and 2013). Its effects are worse in parts of the ocean where carbonic acid concentration are highest (Cowie, 2013) due to their acidity and the structural reliance of the biological community on carbonate.

Table 3. The amount of pollutants in the air caused by dried sugarcane leaf burning

Item	Quantitation (n=6)			
	ppm	mg/100g leaf	kg/ha	%w/w
CO	823±57.1	4,406	731	4.41
NO_2	12.6±1.13	43.7	7.26	0.04
SO_2	19.4±0.91	104	17.3	0.10
CO_2	40,181±648	154,055	25,592	154

Table 4. Total pollutant in the air caused by sugarcane leaf burning each year

Year	Burned sugarcane leaf (ton)	Pollutants (ton)			
		CO	NO_2	SO_2	CO_2
2011/12	10,690,314	471,023	4,672	11,125	16,469,048
2012/13	10,954,310	482,655	4,787	11,400	16,875,750
2013/14	10,939,608	482,007	4,781	11,385	16,853,100
2014/15	11,497,410	506,584	5,025	11,965	17,712,428
2015/16	10,146,923	447,081	4,434	10,560	15,631,924

4. Conclusions

Pre-harvest sugarcane burning induces air pollution with CO, NO_2, SO_2 and CO_2, which potentially affect human health and climate. However, non-sugarcane burning and instead leaving the leaves in the cultivated area can make the soil more abundant with nutrients. As an energy source, sugarcane leaf can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of electricity and biofuel. This research can be applied as a guideline for promoting strategies of non-sugarcane burning, in order to enhance the efficiency of sustainable sugarcane farming management for the sugar industry in Thailand.

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