CHAPTER 9

EFFECTS OF SUGARCANE FIELD BURNING ON CARBON STORAGE IN SUGARCANE BIOMASS

Crop residue management affects both soil fertility and crop productivity, and thus it plays a critical role in the sustainability of cropping systems. Many previous research works have indicated that the burning of crop residue is recognized as a practice having a negative impact on soil by degrading its properties, especially soil organic carbon content, which affects crop productivity (Ball-Coelho et al, 1993; Graham et al., 2002; Hubbert et al., 2006, Kayode et al., 2009). Proper crop residue management that conserves and enhances soil quality will not only improve crop productivity, but environmental quality as well. This chapter aims to present the impact of sugarcane field open burning on crop productivity and carbon storage in sugarcane biomass.

9.1 Methodology

9.1.1 Study site description

The experiment was conducted on a sugarcane farmer's field in Nakhon Sawan province, the same area for the experiment measuring GHG emissions and soil carbon stock, as described in Chapter 7 and 8, respectively, during the growing season of 2012 and 2013. The predominant soil at the experimental site was a clay soil with low organic matter and moderate alkaline. It is classified as Mollisols series according to the USDA classification. Two sites, the sugarcane site with and without burning, were selected for biomass sampling. Each site was 30 m wide by 50 m long. In the burned site, sugarcane was burnt before harvesting and then manually harvested, while mechanical harvested without burning was done in the unburned site. After harvested, sugarcane leaves and tops were returned to the soil.

Land preparation began at the two sites in December 2011 using subsoiler, moldboard plow and disk harrow. Sugarcane variety of Khon Kaen 3 was planted in January 2012 with 12 ton ha^{-1} on 177 cm row spacing. The fertiliser was used on this site with four times as shown in Table 9.1. Also, the planting area was irrigated for four times at the initially period of planting: at 1, 4, 20 and 45 days after planting (DAP). Weed control was done in the first time by manually at 65 DAP and by mechanical, called row cultivation, in the second time at 130 DAP. No herbicide was used for weed control, and no pesticide for insect control.

Table 9.1 Fertilizer application in the experimental site

Fertilizer applications	Day after planting	Application rate (kg ha^{-1})
1) No. 1 (N-P-K: 16-20-0)	0	277
2) No. 2 (N-P-K: 15-7-18)	106	212
3) No. 3 (N-P-K: 46-0-0)	128	118
4) No. 4 (N-P-K: 46-0-0)	151	118

9.1.2 Biomass sampling and analysis

In this study, parameters measured for evaluating the effects of sugarcane field burning on crop productivity, including plant growth over time, cane yield, and sugar yield. During the growing season, the plant growth was estimated by measuring leaf area index (LAI), stem diameter, and stem height in the burned and unburned plots beginning in April 2012 (93 DAP) and continuing at approximately monthly intervals over 7-months. In each plot, five replications, 5 samples per replication, were measured in the same date between 6.00 to 7.00 am. The LAI was measured with a plant canopy analyzer LAI 2200 (Li-Cor Biosciences, Lincoln, NE) which utilizes the sugarcane canopy's gap fraction in some directions below the canopy according to the standard procedure. The mean values and standard errors of these parameters were calculated to evaluate the effect of open burning to the biophysical characteristics of the sugarcane plants.

At the harvesting, sugarcane yield component including the population of harvestable stalks, stalk diameter, and height was estimated from five replications plots in sugarcane burned and unburned treatments, 10 randomly selected stalks per plots, were measured 1 day before harvesting. Together, sugar yield (in term of CCS) in the burned and unburned areas was determined from selected of 10-stalks per plot designated. For the burned plots, sugar yield was measured at two times, before and after sugarcane field burning. Then, the sampling of aboveground biomass was made by a crop cutting experimental plot of 4 rows in width (7 meters) and 10 meters in length. In each treatment, the sugarcane area was divided into five replicated plots. Total above-ground biomass of each experimental plot was determined by collecting the stalks, fresh leaves, dry leaves, and dead leaves at 1 day before harvesting. Sub-samples of each component were weighed, fresh and dried at 70 °C to constant mass for determining moisture content. Then, the dry mass of each component was calculated from the fresh mass and the moisture content, as shown in Equation (9.1). Thereafter, the total dry mass of each plant part was summed as the above-ground biomass.

$$M_D = \left[1-\frac{MC}{100}\right] \text{ x } M_F \qquad (9.1)$$

where M_D is the dry mass of sugarcane biomass (kg m^{-2}), M_F is the fresh mass of sugarcane biomass (kg m^{-2}), and MC is the moisture content on wet mass basis (%)

Furthermore, the belowground biomass generated over sugarcane growing season was collected by hand from three replications of the 1.12 m^2 row section from each designated plot. The experiments were sampled down to the depth of 1 meter for collecting the belowground biomass at the soil layer of 0-30 and 30-100 cm. All biomass samples were washed free of soil and separated carefully by hand. Samples were air-dried for 7 days and dried again at 70 °C to constant mass. Dry weight was recorded.

Thereafter, all 52 samples of all sugarcane partitions in the burned and unburned plots were subject to size to 2 cm-length using a cutting mill (SM 2000, Retsch, Germany). All samples were ground in a ball mill (SM 100, Retch, Germany) and sieved to lesser than 100 microns. The final analysis samples were taken to determine the carbon content in each sugarcane partitioning using the ultimate analysis conducted by Organic Elemental Analysis (OEA) using Flash EA112 (ThemoFinigan, USA). All analyses are performed three times and the detection limit for each element was defined as triple standard deviation of blank. Equations for calculating carbon content in biomass are presented in Equation (9.2) and (9.3) (Kanokkanjana, 2010).

$$K = \left[\frac{A_{STD} - A_{Blank}}{\%STD \text{ x } W_{STD}}\right] \text{ x } 100 \qquad (9.2)$$

$$\%C = \left[\frac{A_{Unk} - A_{Blank}}{\%STD \text{ x } W_{Unk}}\right] \text{ x } 100 \qquad (9.3)$$

where %C = Percentage of carbon content in biomass; K = Constant value for calculating carbon content; A_{STD} = Area under curve of standard chemical; A_{Blank} = Area under curve of blank; A_{Unk} = Area under curve of unknown; %STD = Percentage of carbon in a standard chemical; W_{STD} = Weight of standard chemical sample; W_{Unk} = Weight of unknown sample.

9.1.3 Assessment of carbon storage in sugarcane biomass

The carbon storage in sugarcane biomass considered in this research was based on estimates of annual biomass stock in the aboveground and belowground biomass. A generic methodology to estimate the carbon stock in sugarcane biomass is summarized in Equation (9.4).

$$C_{TOTAL} = \sum_{i=1}^{n} \frac{(D_{AG} \text{ x } \%C_{AG}) + (D_{BG} \text{ x } \%C_{BG})}{100} \quad (9.4)$$

where C_{TOTAL} = Total carbon storage in sugarcane biomass (ton C yr^{-1}); D = Total dry mass of sugarcane biomass (ton yr^{-1}); % C = Carbon concentration in sugarcane biomass (%); AB = Aboveground biomass including cane stalks, fresh leaves, dry leaves, and ground trash; BG = Belowground biomass including stools and roots.

9.2 Results and discussion

9.2.1 Sugarcane plant growth

The average values of plant growth on the burned and unburned treatments are given in Table 9.2. As expected, the mean value of LAI, stem diameter, and height increased with time in both two treatments. There are a positively correlation with the time of crops growing. At the first stage of sugarcane plant growth, during 93 to 158 DAP, the effects of open burning were relatively minor resulting in no difference in plant growth under burned and unburned areas, while increasing difference of the plant growth between the two treatments was found after 158 days of crop growth.

As for the LAI values, the mean LAI increased with time ranging from 0.24 (at 93 DAP) to 2.76 (at 219 DAP). This is comparable to the work of Sandhu et al. (2012), which showed that the mean value of LAI in southeastern United States varied from 0.19 to 2.56 between 107 and 211 DAP. Furthermore, this results in Table 9.2 show that the area which adopted the no-burning sugarcane system tends to be higher than the area with open burning system. The stem height was also higher in the unburned area than in burned area, which could be due to a drought which occurred in this area. The unburned area tends to have high soil moisture content than the burned area resulting in high plant growth in the unburned treatment.

Table 9.2 Average values and standard errors of the biophysical parameters of sugarcane fields during the growing season of sugarcane

Plant characteristic	Day after planting (DAP)				
	93	123	158	200	219
Burned area					
LAI (m^2. m^{-2})	0.25 (0.10)	0.56 (0.10)	1.15 (0.15)	1.68 (0.01)	2.34 (0.16)
Stem diameter (cm)	1.92 (0.03)	2.34 (0.02)	3.42 (0.08)	3.41 (0.06)	3.47 (0.08)
Stem height (cm)	11.78 (0.74)	15.74 (0.35)	36.44 (2.05)	55.76 (3.19)	72.52 (2.38)
Unburned area					
LAI (m^2. m^{-2})	0.24 (0.16)	0.62 (0.09)	1.38 (0.11)	2.10 (0.07)	2.76 (0.05)
Stem diameter (cm)	1.89 (0.04)	2.53 (0.08)	3.54 (0.10)	3.55 (0.03)	3.63 (0.02)
Stem height (cm)	10.72 (0.72)	17.60 (1.47)	42.44 (2.40)	62.04 (2.62)	78.76 (3.42)

9.2.2 Sugarcane biomass

At the harvesting periods, sugarcane yield components in the burned and unburned plots are given in Figure 9.1. The stem diameter of cane stalk was found a smaller size in the burned plot than in the unburned plot. However, this study did not find the difference among treatments for sugarcane height, and stalk population.

In addition, sugar yield, which is determined in terms of the sugar content of cane as it is purchased by the sugar mill, in the burned and unburned plots was measured 1 day before harvesting. For the burning management, the measurement was done in two times; before and after burning. The significant difference was found in sugarcane yield between two treatments only before burning. The unburned area has 6.36% higher in sugarcane yield than the burned area in this time. However, the sugarcane yield increased approximately 1.88% after burning that resulted to no significant different in sugar yield between burned and unburned treatments as shown in Figure 9.2.

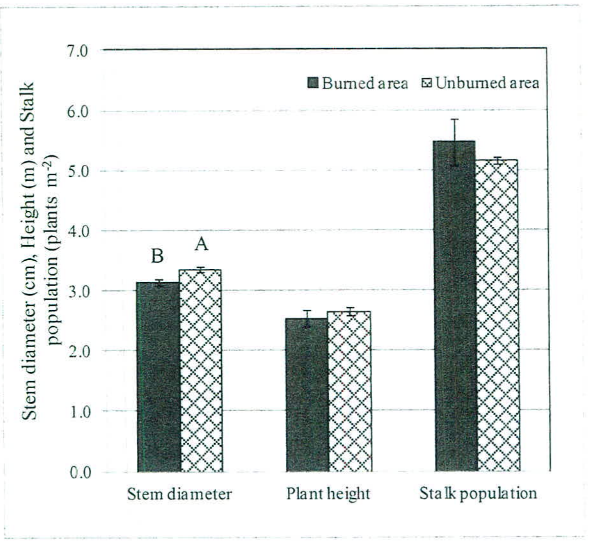

Figure 9.1 Sugarcane yield component in the area with and without burning. Bar indicates the standard errors about the mean. The values with the same capital letter or with no letter are not significant ($p \leq 0.05$).

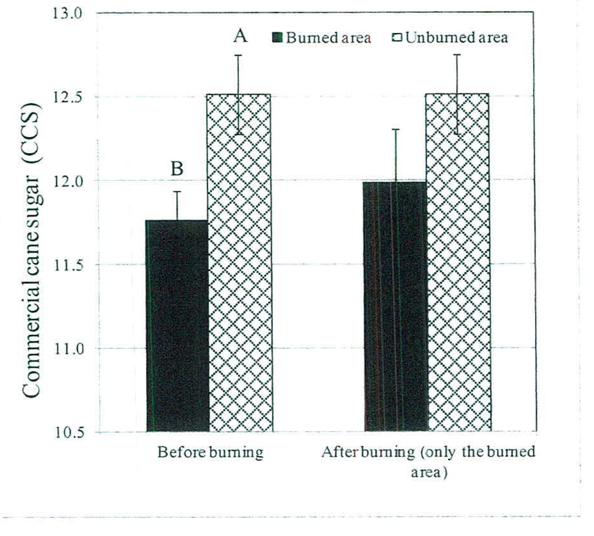

Figure 9.2 Sugar yield in the burned and unburned treatments. Bar indicates the standard errors about the mean. The values with the same capital letter or with no letter are not significant ($p \leq 0.05$).

The total sugarcane biomass including the above-ground and below-ground biomass was estimated during the harvesting season. The negative effect that burning had on sugarcane biomass compared with no-burning management is shown in Figure 9.3. The results indicated that the burning sugarcane biomass caused about 11% reduction of total sugarcane biomass (33.88 and 37.45 Mg ha^{-1} for burned and unburned systems respectively). The dry mass of the total aboveground biomass is about 29.07 and 32.76 Mg ha^{-1} for the burned and the unburned treatments, respectively. Considering the dry mass of belowground biomass in the top 100 cm soil layer, there was about 4.81 Mg ha^{-1} for the burning management and 4.69 Mg ha^{-1} for no-burning management. The overall increase in sugarcane biomass under unburned practice is mainly due to increase soil fertility, which had a direct effect on crop productivity. It could be noted that change in crop residue management would help sustain crop productivity, and would have noticeable consequences in global carbon budget when large areas are involved.

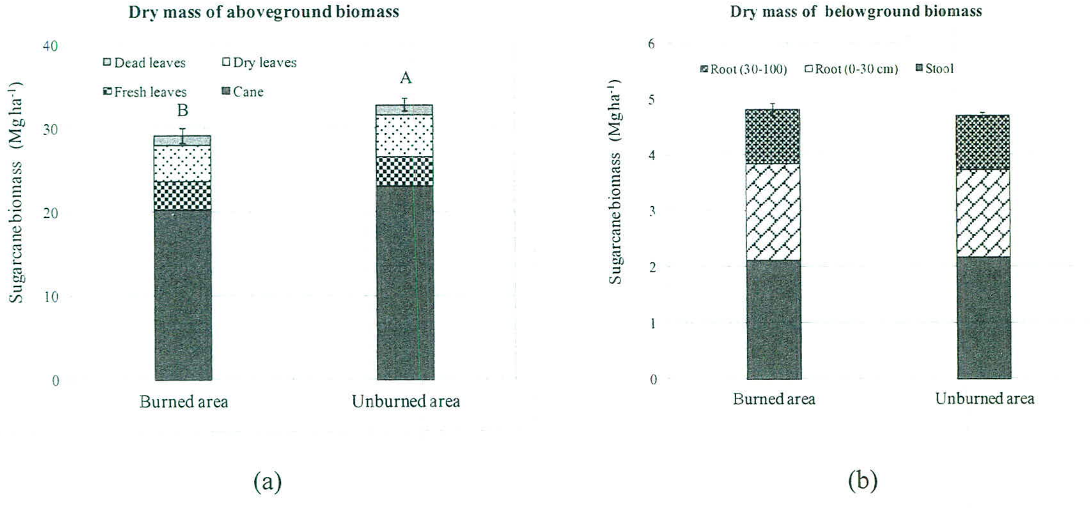

Figure 9.3 Effects of open burning on total above-ground biomass in sugarcane plantation areas. Standard errors are represented by the vertical line on the bars. The values with the same capital letter or with no letter are not significant ($p \leq 0.05$).

9.2.3 Carbon storage in sugarcane biomass

The carbon concentrations in each partitioning of sugarcane had no measurable difference between burned and unburned areas, as shown in Figure 9.4. The carbon content in cane stalk in this study, approximately 43-44%, is to close to the value presented in the literature ranged from 44% to 45% (Jorapur, 1997; Garivait, 2006; Demirbas, 2010). The finding shows the value of carbon concentration in sugarcane leaves ranged from 40% to 43%. There are also agree with the previous studies that reported the carbon content in sugarcane leaves is varied from 40% to 45% (Jorapur, 1997; Yuttitham, 2009). While, the carbon content in stool (41-44%) and root (39-40%) measured in this study is smaller than the work of Yuttitham (2009): 46% for stool and 42% for root. This is probably due to difference in sugarcane cultivar and farm management practices.

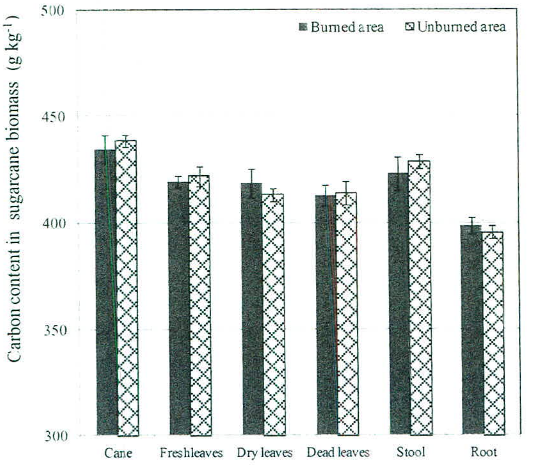

Figure 9.4 Carbon content in sugarcane biomass for burned and unburned treatments. Bar indicate the standard errors about the mean. The values with the same letter or with no letter are not significant ($p \leq 0.05$).

Table 9.3 Total carbon in sugarcane biomass at the experimental site

Sugarcane partitioning	Carbon storage in biomass (Mg C ha^{-1})	
	Burned area	Unburned area
1. Aboveground biomass	12.47 (0.33)	14.15 (0.34)
1.1 Cane stalks	8.81 (0.15)	10.12 (0.27)
1.2 Sugarcane residue	3.67 (0.18)	4.03 (0.10)
2. Belowground biomass		
2.1 Soil depth: 0-30 cm	1.58 (0.07)	1.55 (0.00)
(1) Stool	0.89 (0.05)	0.93 (0.05)
(2) Root	0.69 (0.02)	0.62 (0.05)
2.2 Soil depth: 0-100 cm	1.97 (0.05)	1.92 (0.02)
(1) Stool	0.89 (0.05)	0.93 (0.04)
(2) Root	1.08 (0.01)	1.00 (0.05)
3. Total biomass		
3.1 Soil depth: 0-30 cm	14.05 (0.39)	15.70 (0.35)
3.2 Soil depth: 0-100 cm	14.44 (0.38)	16.07 (0.37)

The annual estimates of carbon stock in biomass in this study were calculated using Equation (9.4) and summarized in Table 9.3. The result indicated that mean carbon storage in sugarcane biomass has approximately 12% reduction in the area with continuous burning compared to the no-burning area. Total carbon storage in sugarcane biomass is about 14.05 and 15.70 Mg C ha^{-1} when considering belowground biomass at the 0-30 cm. At the 0-100 cm soil depth, total carbon storage is 14.44 Mg C ha^{-1} for burned area and 16.07 Mg C ha^{-1} for unburned area. This confirmed the beneficial effect that no-burning had on increased carbon storage in sugarcane biomass compared to burnt cane management. There was a consistent benefit for no burning over burning management.

9.3 Summary of findings

This study found that the burning system had direct effects on sugarcane production as well as the carbon storage in sugarcane biomass. Indeed, about 11% reduction of the total biomass was found in the area with field burning practice comparatively to the area without burning over the past 5 years. Total carbon storage in biomass was greater under the unburned area than the burned area, approximately 1.65 Mg C ha^{-1}. Results clearly showed that the burning system has a reduction potential of crop productivity and carbon storage in sugarcane biomass. The burning sugarcane biomass may hinder a sustainable cropping system.