

CHAPTER 5

CARBON FLOWS AND BUDGETS IN SUGARCANE FARM

5.1 Introduction

Field management in agriculture has the potential to mitigate greenhouse gases by sequestering carbon in soils through input crop residues and other organic material, and managements of farm activities. In Thailand, study on carbon dynamics in the sugarcane field that could be used to support carbon flow and net carbon budget estimate are very limited. Such estimate is necessary to define the emission baseline and a subsequent mitigation potential evaluation. To estimate carbon budget, this chapter is dealt with measurements of soil respiration, crop residues decomposition, energy utilization from farm activities. The field experiment was designed to measure *in situ* field CO₂ and CH₄ flux, soil characteristics and sugarcane biomass decomposition. The sugarcane farm management was also studied by interviewing sugarcane farmers in the study area. The results of the measurements and experiments and carbon budget in the whole agriculture part are reported and discussed in this chapter.

5.2 Field measurements of CO₂ and CH₄ fluxes

CO₂ and CH₄ were produced in soil as a result of root respiration, animal and microbial activity during decomposition of organic material or crop residue. They represent the main pathway of carbon loss and nutrient recycling from the soil process (Peterson *et al.*, 1998). The measurement results from the sugarcane fields show that the average monthly soil CO₂ flux ranged from 204±56.9 to 1327.7±74.5 mg CO₂/m²/h. The average annually soil CO₂ flux is 645.08±367.48 mg CO₂/m²/h. In the first period of planting (May) CO₂ flux was high (1327.7±74.5 mg CO₂ /m²/h) which related to high rate of sugarcane biomass decomposition (Figure 5.7, section 5.3.2). CO₂ flux was lower in January 2007 (204±56.9 mg CO₂ /m²/h) which was the last period of sugarcane planting. Soil CO₂ fluxes tended to increased from March to May 2006 on the first period of sugarcane biomass decomposition then trend to decrease on June to July. They peak on October which may have been resulted from pesticide and liquid swine manure addition (on August 11 and September 10).

Many studies have demonstrated that soil CO₂ and CH₄ fluxes vary with ecosystems. They also vary with time of year and soil environment, mainly on soil temperature and soil moisture (Hanson *et al.*, 1993; Whalen, and Reeburgh, 1996). In this study the CO₂-flux did not statistically related with soil temperature ($R^2=0.0011$, $p>0.05$) but statistically related with soil moisture at 95 % confidence level ($R^2= 0.5227$, $p<0.05$) (Figure 5.1 and 5.3).

The average CH₄ emissions through the whole planting period indicate the net sink of CH₄. However, during some periods there were minor emissions. The CH₄ flux ranged from -0.18 ± 0.09 to 0.24 ± 0.02 mg CH₄/m²/h (Figure 5.2). The average throughout a year of measurement is -0.059 ± 0.145 mg CH₄/m²/h. When compared the monthly CH₄ flux with soil temperature and soil moisture throughout the study period, CH₄ flux was not statistically significant correlated with either soil temperature or soil moisture ($R^2=0.333$, $p>0.05$ and $R^2=0.0257$, $p>0.05$, respectively) at 95 % confidence level (Figure 5.1 and 5.2).

The total values estimated from the whole planting period for CO₂ and CH₄ emissions were 60.09 ton CO₂/ha/yr or 16.39 ton C/ha/yr and -0.0054 ton CH₄/ha/yr or -0.11 ton CO₂-eq/ha/yr, respectively. The net soil carbon emission from sugarcane plantation was approximated to 16.39 ton C/ha/yr, based on CO₂ –C flux. Annual soil CO₂ flux rates from this study were in the similar ranges as those reported elsewhere (Agustin *et al.*, 2004; Scala Jr. *et al.*, 2006).

It is noted that on annual basis, the sugarcane farms under the current study are the net CH₄ sink. The CH₄ sink are soils where CH₄ is oxidized to CO₂ and assimilated into microbial biomass. This is a biological process that occurs under aerobic condition. The methanotrophic bacteria are unique in their ability to use CH₄ as a carbon and energy source (Hütsch, 2001). In general a significant increase in CH₄ sink was observed in the order arable < grassland < forest respectively. In agriculture soil, it is common that the minor methane uptake is observed. However, CH₄ uptake processes in soils are negatively affected by agricultural practices for example: N fertilizer, application of organic manure, soil pH and liming, land use and soil tillage, crop management. CH₄ oxidation is inhibited by inorganic N fertilizer application (Willison *et al.*, 1996). Many studied in laboratory found a strong inhibitory effect of NH₄⁺ on CH₄ oxidation in forest, grassland, peat and landfill cover soils, respectively (Bender and Conrad, 1994a; Flessa *et al.*, 1996b; Hütsch *et al.*, 1996; Hütsch, 1998a, 2001). NH₄⁺ acts as a competitive inhibitor of the

methanotrophic bacteria and the effect was not fully reversible. Besides N fertilizer applications to arable and grassland N inputs via wet and dry deposition also affect the CH₄ oxidizing ability of soils. Therefore long term farm yard manure application to arable soils caused an inhibition of CH₄ oxidation. Previously study concluded that a significant land use effect exists with considerably higher CH₄ oxidation rates under forest or grassland than under agriculturally used land. On filed sites CH₄ uptake increased with reduced tillage intensity and a very different vertical zonation was observed (Hütsch, 2001).

On the other hand, general methane can be produced in anaerobic conditions. The main agriculture area for CH₄ source is rice paddy field. In agricultural upland soil methane emission was occurred in anaerobic condition or some farm management for example: after animal manure application, particularly slurry can cause CH₄ emission immediately after application. The previous study found that dissolved CH₄ that volatilizes after application, and microbial degradation of short-chain volatile fatty acids present in the pig slurry, were mainly responsible for the observed CH₄ emission (Sommer *et al.*, 1996).

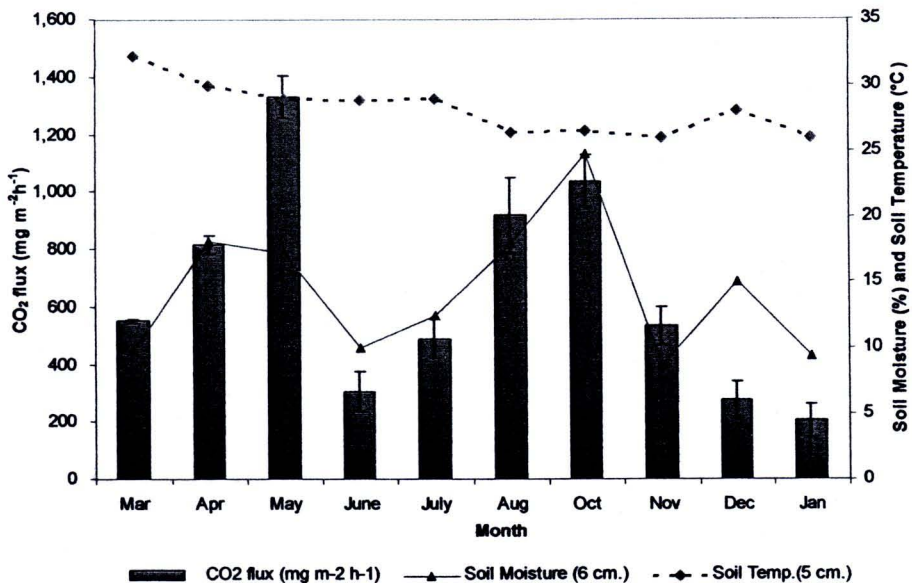


Figure 5.1 Average of soil CO₂ flux from sugarcane field during March 2006 to February 2007, soil temperature at 5 cm depth and soil moisture at 6 cm depth. Error bars represent standard deviation of four replications (*mean ± S.D.*)

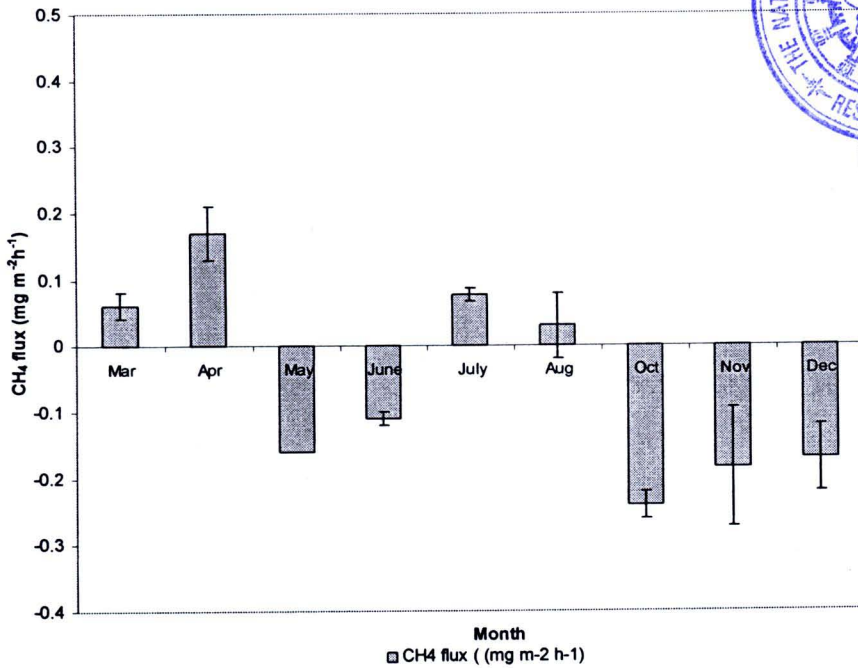
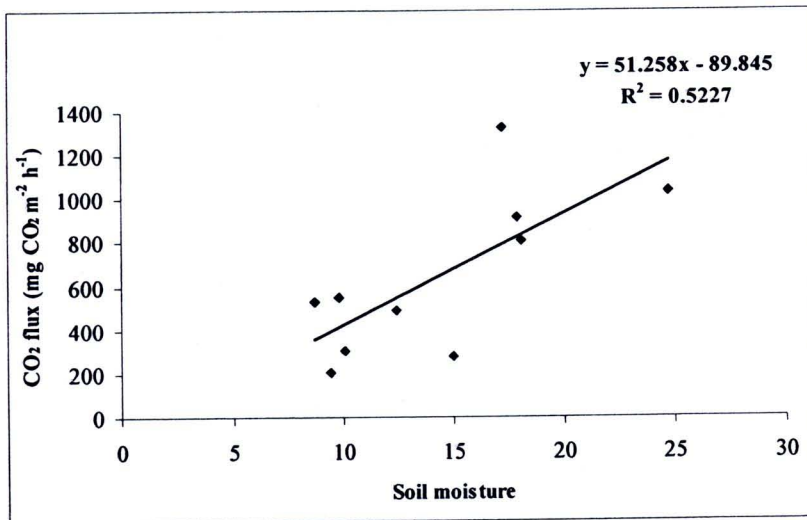
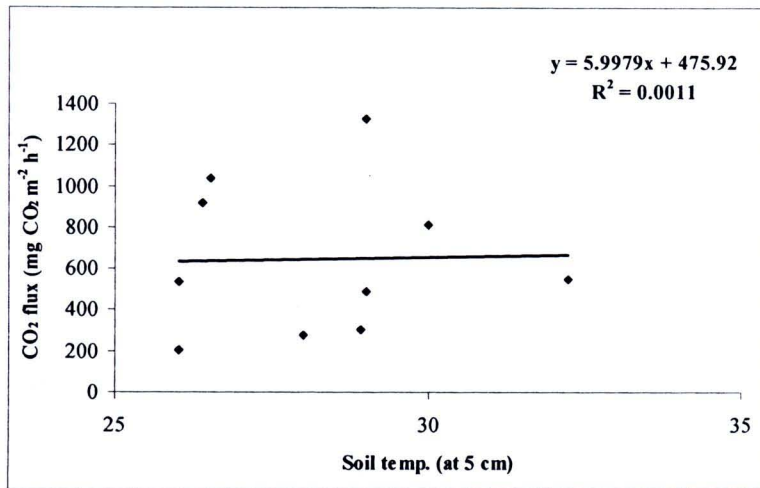


Figure 5.2 Average of soils CH₄ flux on sugarcane field from March to December 2006, soil temperature at 5 cm depth and soil moisture at 6 cm depth. Error bars represent standard deviation of four replications (*mean ± S.D.*).



(a) Relationship between soil CO₂ flux and soil moisture ($p=0.018$)



(b) Relationship between CO₂ flux and soil temperature ($p=0.798$)

Figure 5.3 Relationship between soil CO₂ flux and soil moisture and soil temperature

5.3 Field measurements of sugarcane biomass decomposition

In this part, sugarcane biomass decomposition in the field was studied. In addition to measurement the mass loss during sugarcane growth (296 days), the lignin and holo-cellulose content, total C, and total N were also measured. Decomposition at two depths was carried out, at top soil and 15 cm depth. The results of this study will assist in explaining soil carbon content and soil surface emission of CO₂ and CH₄.

5.3.1 Lignin and Holo-cellulose contents

Decomposition of litter influences the amount of carbon that is retained in the litter layer and also the amount that is transferred to soil. Normally, the easily decomposable organic materials such as sugar will be decomposed first, followed by hemi-cellulose, cellulose, lignin, waxes and phenols. This is depending on the microorganism's activity; bacteria, fungi and the amount of such fraction.

Typical, the components of plant consist of cellulose (40-60% of dry weight), hemi-cellulose (20-40 % of dry weight) and lignin (10-25% of dry weight) Table 5.1 shows composition of sugarcane biomass from available literature (Bob, 2002). Table 5.5 gives the sugarcane components properties before being used in the decomposition study.

Table 5.1 Biomass composition (% by dry weight), (Bob, 2002)

Biomass sources	Sugars	Cellulose	Hemi-cellulose	Lignin	Other
Sugarcane (prepared cane) ^a	43	22	15	11	9
Sugarcane leaves	-	36	21	16	27
Sugarcane (whole plant)	33	25	17	12	13
Bagasse	3	38	27	20	12

^a Prepared cane-cane after washing off mud and rocks: Still has some leaves and water.

This is processes to source (sugar), molasses and bagasse.

In this study, lignin and holo-cellulose content were measured in different sugarcane parts and at two time points before planting and at harvest (Table 5.2 and 5.3). The results show that the initial lignin content varied from 12 to 21 g/100 g dry weight biomass and holo-cellulose (carbohydrate fraction in plant) varied from 52 to 67 g/100 g dry weight biomass (Table 5.2). During the last period of sugarcane decomposition study (296 days), lignin content was highest for root followed by shoot, leaf and leaf sheath (8.37, 8.19, 5.83 and 2.18 on g/100 g dry weight biomass respectively). Holo-cellulose content was highest in root and followed by shoot, leaf and leaf sheath (21.00, 20.88, 11.22 and 7.03 on g/100 g dry weight biomass respectively) (Table 5.2).

It was found that lignin and holo-cellulose content was not completely decomposed at the end of the experiments (296 days). In the top soil, 82.28 % of initial lignin content in leaf sheath was decomposed. In the shoot, leaf, and root, 64.93 % 62.87 % and 56.41 % of initial lignin content were decomposed. However, a larger degree of lignin decomposition was found at 15 cm depth. The changes in lignin content of four sugarcane components: leaf, leaf sheath, root and shoot varied at two different depth levels. There was not significant difference between depths ($p > 0.05$) (Table 5.2). In the part of holo-cellulose was represented in Table 5.3. The changes in holo-cellulose varied at two different depth levels, and there was significant difference between soil depth ($p < 0.01$, by using T-test).

It can be conclude that lignin and holo-cellulose was decomposed about 56-82 % of the initial lignin and holo-cellulose content, it remained 12-34% from the initial lignin and holo-cellulose content. Eklind and Kirchman (1999) studied on carbon turnover in difference plant species in laboratory in composting systems. They controlled the factors before experiments: C to N ratios of 22-34 and a litter C proportion of about 50% organic

C, water content of 58-65%. They found that lignin and holo-cellulose was decomposed about 50 % during more than 590 days. Initial lignin content was not correlated to organic matter loss at the beginning of composting period (590 days).

Table 5.2 Changes in lignin content for four sugarcane components at two different depth levels

Sugarcane components	Lignin (g/100 g dry weight biomass)			
	Topsoil (0 cm)		Depth (15 cm)	
	Initial (0 day)	Final (296 days)	Initial (0 day)	Final (296 days)
Leaf	15.70	5.83	15.70	4.49
Leaf sheath	12.30	2.18	12.30	0.35
Shoot	21.10	7.40	21.10	8.19
Root	19.20	8.37	19.20	8.2

Table 5.3 Changes in Holo-cellulose fraction of four sugarcane components at two different depth levels

Sugarcane components	Holo-cellulose (g/100 g dry weight biomass)			
	Topsoil (0 cm)		Depth (15 cm)	
	Initial (0 day)	Final (296 days)	Initial (0 day)	Final (296 days)
Leaf	66.70	11.22	66.70	6.46
Leaf sheath	58.10	7.03	58.10	0.57
Shoot	54.20	20.88	54.20	14.85
Root	52.20	21.00	52.20	13.55

5.3.2 Dry mass losses, decomposition rate and sugarcane biomass nutrient recycling (Total C, Total N and C:N ratio)

5.3.2.1 Total C

Litter bags were placed on the field on 9 March, 2006 (at planting time). Four hundred and thirty two litter bags were placed on topsoil and 432 litter bags were placed at 15 cm depth, in the 72 rows (six bags in each row) distributed around the study site. Four sugarcane component samples (18 litterbags per sugarcane component, at top soil and 15 cm depth, totally 72 samples/month) were taken back to laboratory every month for dry weight loss, total C, total N and C to N ratio analysis.

A first order kinetic model was used to estimate decomposition rate of sugarcane biomass (Figure 5.5-5.6). Generally, the rate of decomposition was rapid during initial stages and declined towards the end of cropping season (Spain and Hodgen, 1994). It was found that among various biomass components, decomposition rate was highest for leaf sheath followed by leaf, shoot, and root (17.76, 16.94, 6.32 and 2.74 g/month respectively) (Table 5.4). As a result, root had the slowest turnover time (9.49 months) while leaf sheath had the fastest turnover time (2.67 months). Placing biomass at different depths also results in different decomposition rates. Placing it at 15 cm depth has resulted in a better decomposition than at the top soil (Table 5.6). The highest decomposition rate occurred at 15 cm soil depths level much more related to biological action and micro-environmental conditions within litter and soil horizons, such as moisture the changing litter quality. At the end of the experiment, 88 to 98 % of mass loss was observed (Figure 5.4). Osono *et al.*, 2006 demonstrated that both litter depth and decomposition stage were important factors affecting fungal colonization to decomposition. There was statistically significant different between soil depth on dry weight loss of leaf, leaf sheath and shoot ($p < 0.01$). But for root, there was no significant difference in decomposition rate between soil depth ($p = 0.05$), (Table 5.6).

The k value of sugarcane biomass decomposition ranged from 0.12 to 0.37 (Table 5.6). Sugarcane biomass in this study was decomposed within 3 - 10 months. This is consistent with the results reported in several countries that sugarcane biomass can be decomposed within 12 months.

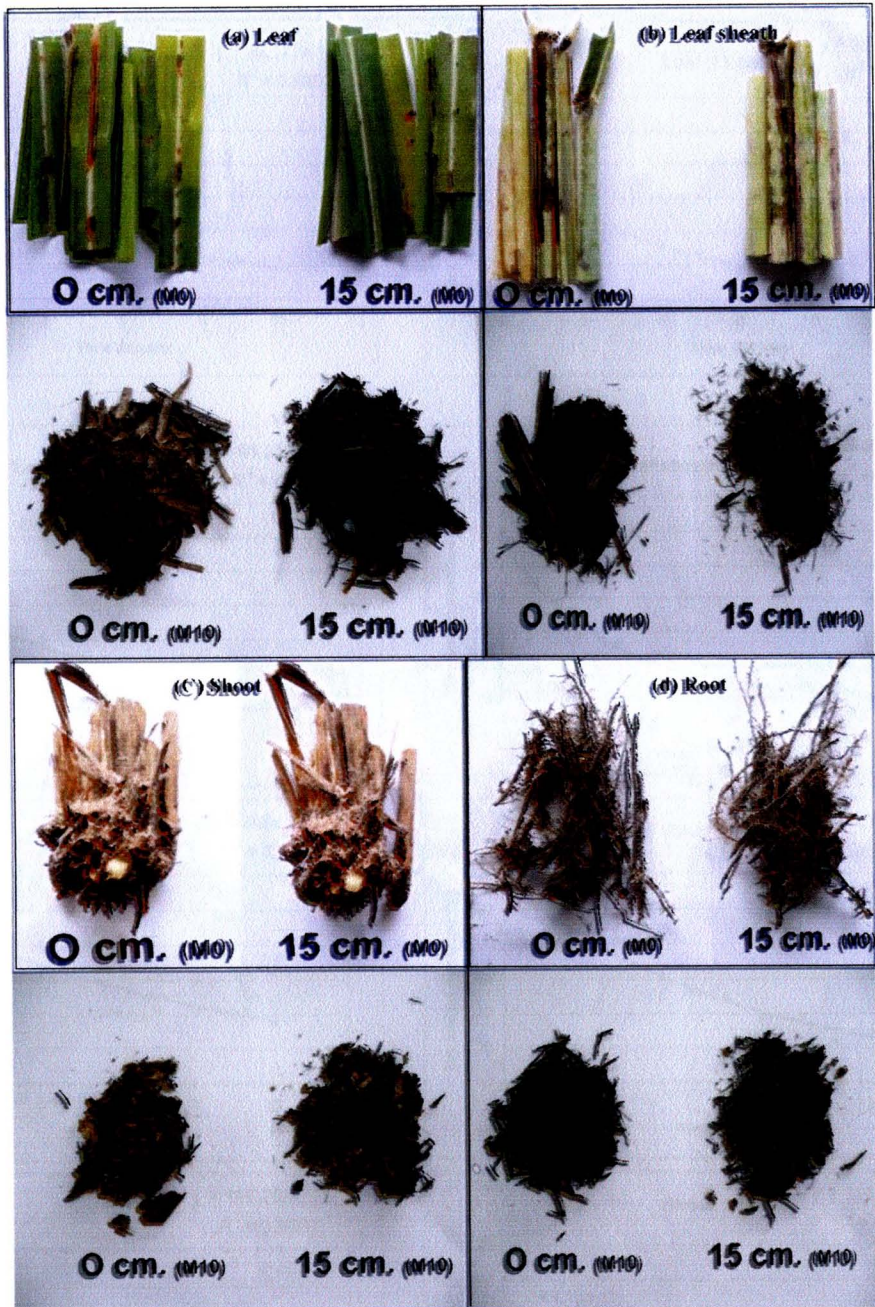


Figure 5.4 Sugarcane components sampled before planting (0 days; 9 March, 2006 and at the 10th month (296 days, 1 January, 2007), (M0=sampled before planting), (M10=sampled at 10 months)

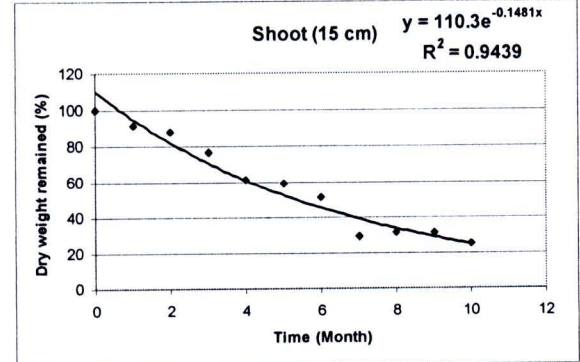
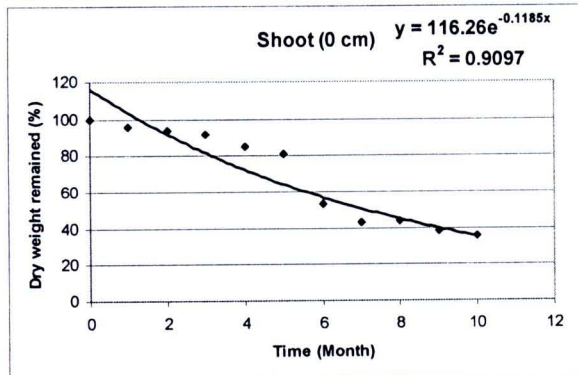
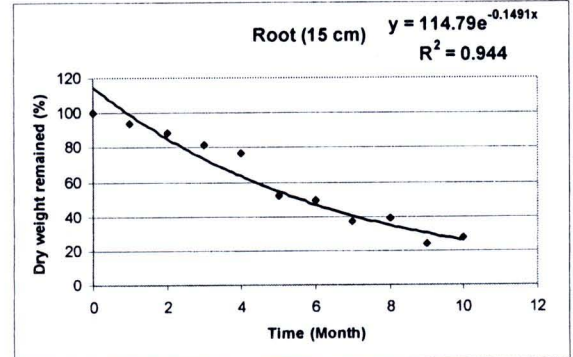
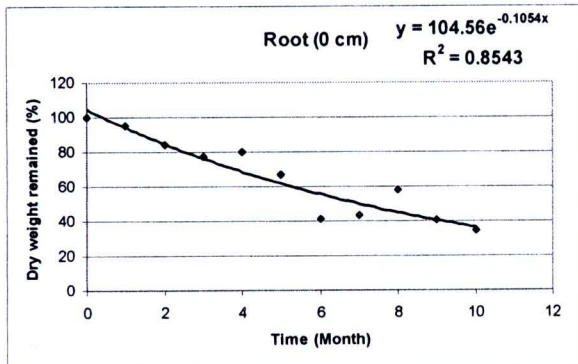
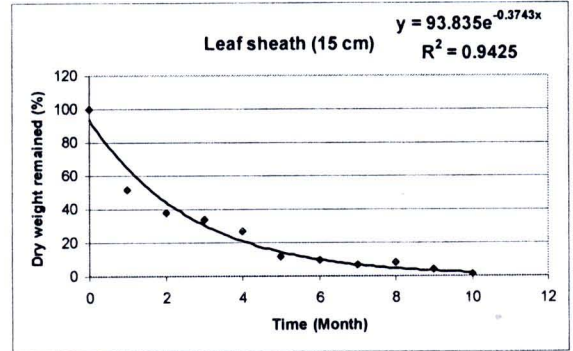
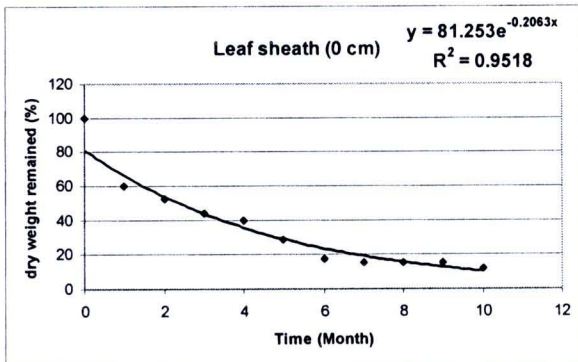
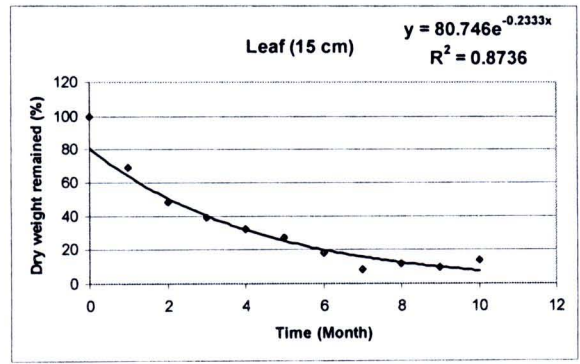
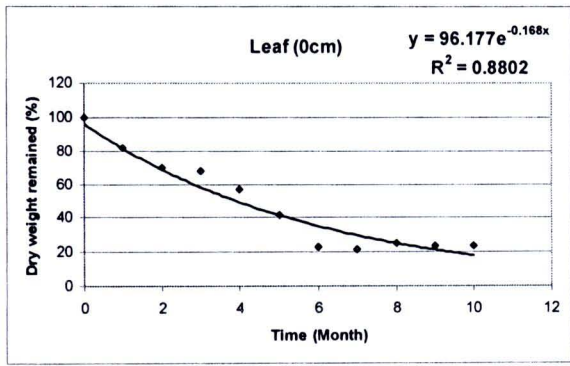
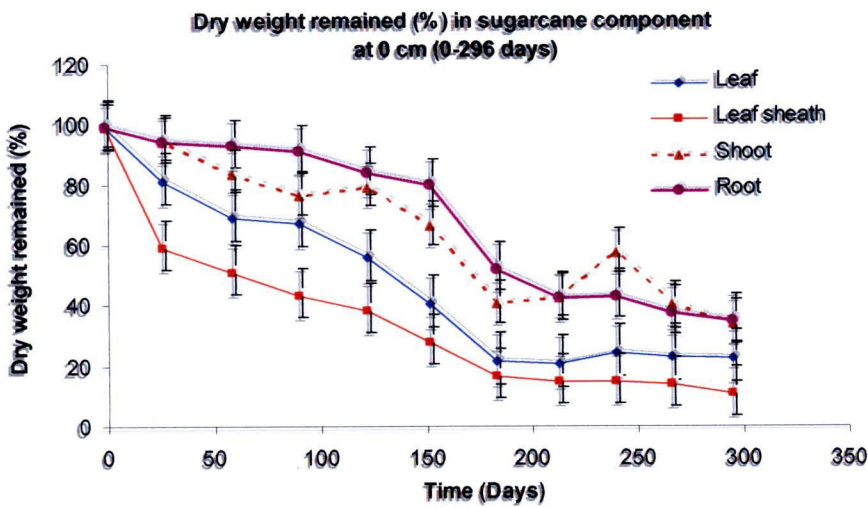


Figure 5.5 Example of time course of sugarcane biomass decomposition during the planting period

Table 5.4 Weight losses, rate constant and turn over time for sugarcane biomass decomposition

	Leaf		Leaf sheath		Root		Shoot		
	Dry weight remained (%)		Dry weight remained (%)		Dry weight remained (%)		Dry weight remained (%)		
	0 cm	15 cm	0 cm	15 cm	0 cm	15 cm	0 cm	15 cm	
% Dry weight before experiments	100	100	100	100	100	100	100	100	
9-Mar-06	0	100	100	100	100	100	100	100	
5-Apr-06	27	82.18	68.96	59.95	51.62	95.39	93.77	95.41	91.07
8-May-06	60	70.06	48.04	52.08	38.10	84.43	88.43	93.72	88.20
8-Jun-06	91	67.91	38.91	44.23	33.70	77.13	81.26	91.95	76.62
10-Jul-06	123	56.64	31.97	39.42	27.16	79.97	76.56	84.68	61.28
10-Aug-06	153	41.38	27.20	28.79	11.90	67.23	52.25	80.58	59.42
10-Sep-06	184	22.62	17.81	17.64	9.85	41.4	49.14	53.00	51.38
9-Oct-06	214	21.68	8.06	15.66	6.87	43.37	36.73	43.22	29.66
6-Nov-06	241	25.23	11.6	15.57	8.36	58.18	38.95	43.84	31.20
2-Dec-06	267	23.93	9.72	15.07	3.92	41.00	24.2	38.42	31.63
1-Jan-07	269	23.33	13.99	11.84	1.2	34.75	27.3	35.77	25.32
Initial weight (g)	70.29	72.63	47.32	47.45	18.54	18.4	40.23	42.66	
<i>k</i> (per month)	0.168	0.2333	0.2063	0.3743	0.1054	0.1491	0.1185	0.1481	
R ²	0.8802	0.8736	0.9518	0.9425	0.8543	0.944	0.9097	0.9439	
Decomposition rate (g/month)	11.81	16.94	9.76	17.76	1.95	2.74	4.77	6.32	
Turn over time (months)	5.95	4.29	4.85	2.67	9.49	6.71	8.44	6.75	



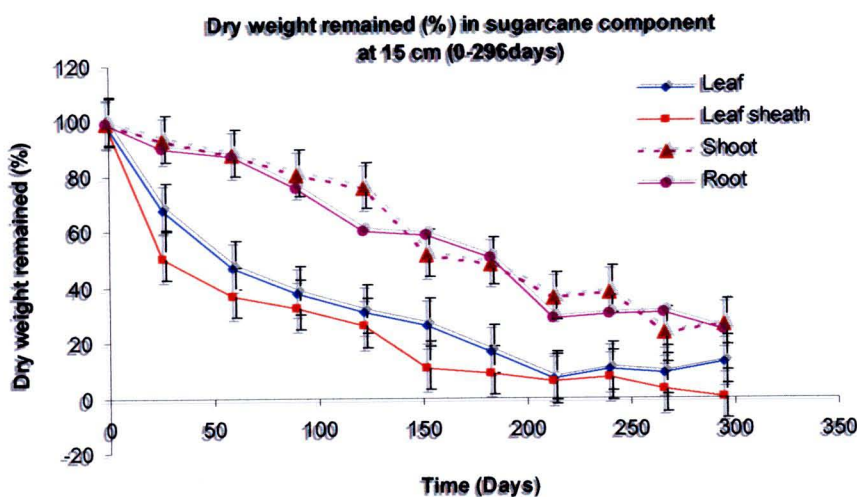


Figure 5.6 The dry weight remained at 0 and 15 cm depth during the planting period (0-296 days)

Thus, the results show that it is clear that most of sugarcane biomass (80%) was decomposed within 1 year. The amount of root that decomposed is about 0.65 ton/month and shoot is 0.95 ton/month. For leaves at 15 cm depth the decomposition capacity is 5.23 ton/month.

In addition, the results of the initial total C in different sugarcane component varied from 42 to 46 g/100 g dry weight biomass. Total C concentration was highest in shoot (46 g/100 g dry weight biomass), followed by leaf (45.24 g/100 g dry weight biomass), leaf sheath (44.13 g/100 g dry weight biomass) and root (41.6 g/100 g dry weight biomass), respectively (Figure 5.7). Total C concentration of all sugarcane components gradually decreased from initial to the last day of the decomposition study (296 days) (Figure 5.7). At the last day of the experiments (296 days) total C in different sugarcane components varied from 0.40 to 9.36 g/100 g dry weight biomass. At the end of sugarcane plantation period 0.96-20.34 % of total C in sugarcane component was remained. In addition, decomposition at different soil depth has also resulted in a significant different amount of total C remained ($p < 0.01$), except total C in root.

5.3.2.2 Total N

At the beginning of the decomposition study, the total N of the different sugarcane components varied from 0.40-0.82 g/100 g dry weight biomass. The highest was recorded

in sugarcane leaf and lowest was recorded in shoot (Figure 5.7). At the end, total N in sugarcane components of two depth level was not significant difference ($p>0.05$). There was also no difference in total N content among sugarcane components. Along the course of decomposition study, total N concentration of sugarcane component was gradually decreased from initial to 184 days. Then, they were increased at around 214 days and decreased to 0.01 to 0.18 g/100 g dry weight biomass at final (296 days) of decomposition study (Figure 5.7). The peak after 214 days was possibly because of addition of liquid swine manure on 10 September 2006 (the 184 days for this experiment), at a rate of through 2.08-2.708 kg N/ha (Mean= 2.394 kg N/ha).

At the last days of the experiments total N in different sugarcane component varied from 0.06 to 0.18 g/100 g dry weight biomass. The highest of total N concentration was shown in leaf at 15 cm depth. Moreover, the initial total N in sugarcane leaf had shown the highest total N concentration. At the end of the sugarcane plantation 2-25 % of nitrogen remained in sugarcane components.

5.3.2.3 C:N ratio

In this study, initial C:N ratio of the sugarcane components varied from 55-114 (Figure 5.4). The highest was recorded in shoot (114:1) and lowest was recorded in leaf (55:1). On the last days of the experiments C:N ratio in different sugarcane component varied from 32 - 68. The highest was recorded in root at top soil (68:1) and lowest in leaf (32:1). Based on the initial C:N ratio values as the indicator of decomposability (Nimpha *et al.*, 1999), leaf should give the fastest decomposition because C:N ratio in leaf falls within a appropriate range for microbial activity. In deed, leaf sheath showed the fastest decomposition rate (Figure 5.7).

There are some previous studies that have reported on C:N ratio of about 51:1 in sugarcane components (Sneh *et al.*, 2005). Previous studies in Thailand reported that C:N ratio from initial sugarcane residue was 102:1 (Saowakon *et al.*, 2008). In the literature the appropriate C:N ratio for sugarcane residue decomposition was 50:1.

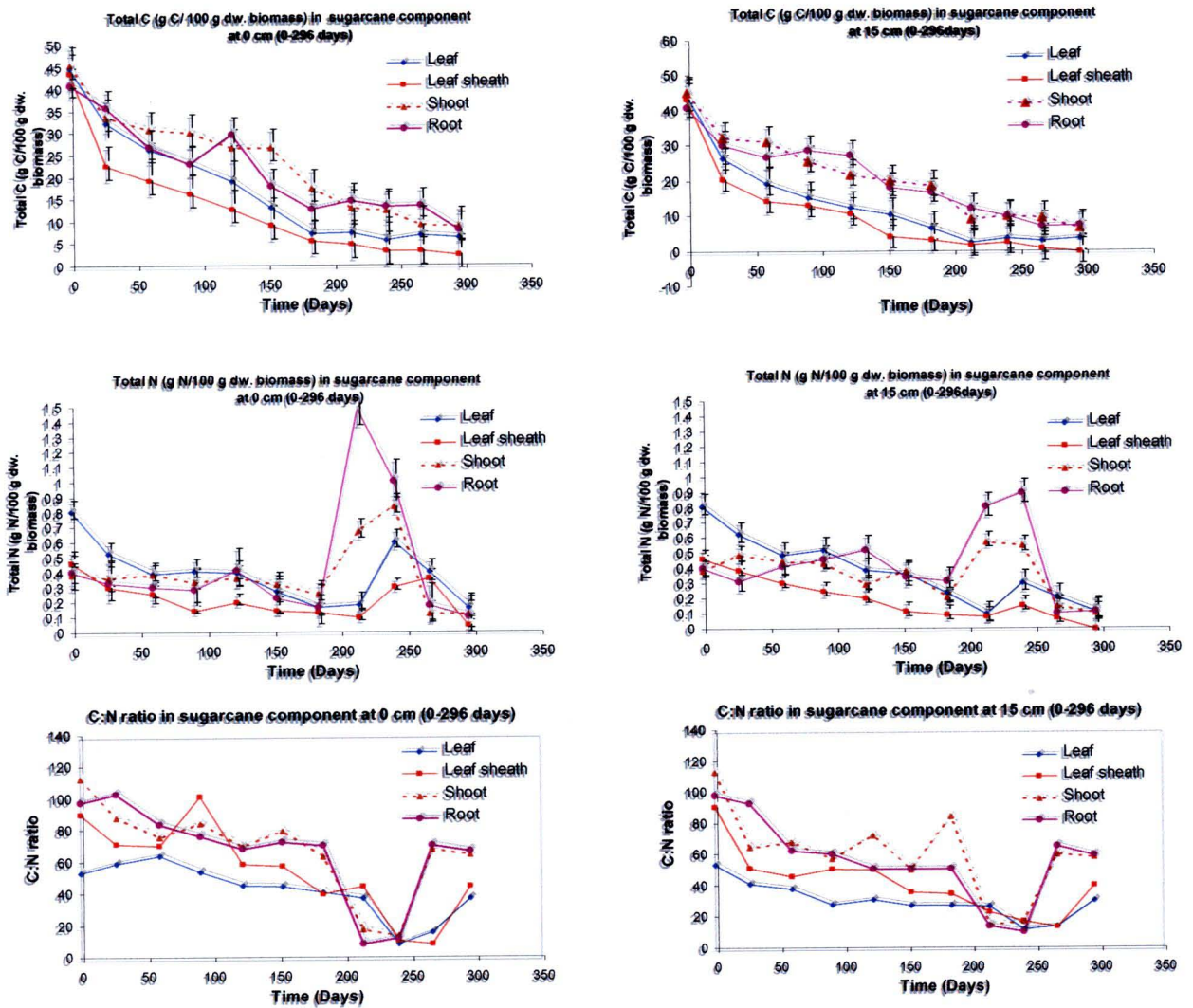


Figure 5.7 Total C, Total N and C:N ratio during decompose (0 to 296 days) of sugarcane components (leaf, leaf sheath, shoot and root) at 0 and 15 depth level (\pm standard deviation from 3 replications)

Table 5.5 The sugarcane components properties before decomposition study: leaf, leaf sheath, shoot and root (mean \pm standard deviation from 3 replications)

Sugarcane components	Total C g/100 g dry weight biomass	Total N g/100 g dry weight biomass	C:N	Moisture Contents
Leaf	45.24 \pm 0.35	0.82 \pm 0.06	55	149.31 \pm 2.49
Leaf sheath	44.13 \pm 0.17	0.48 \pm 0.02	92	227.83 \pm 0.67
Shoot	46.00 \pm 0.22	0.40 \pm 0.03	114	144.05 \pm 6.87
Root	41.60 \pm 0.34	0.42 \pm 0.01	99	18.03 \pm 1.66

5.4 Field measurements of biomass after harvest, sugarcane plant part and root density

The amount of top and leaves after harvest was measured in the field by using 1 m² of plot and weight for each plot for 10 representative plots. The results show the amount of sugarcane biomass (top and leaves) of 1.72±0.4 kg/m² or 17.20±4.0 ton dry matter biomass /ha/yr or 6.68 ton C /ha/yr (Table 5.6).

In addition, sugarcane root density measurement was conducted by core method (section 3.3.3 on chapter 3). Through a stainless steel tube (5 cm inner diameter and 5.1 cm height) soils with root were collected at 0-15 cm depth. Root were separated and carefully washed free of soil by placing the soil in a large-sieved container. Washed root were then oven dried and weight. Sugarcane root density was calculated. The average from 15 samples of root density was 0.0029 ±0.0021 g/cm³ or 2.9±2.1 mg/cm³ or 4.35 ton/ha or 1.81 ton C/ha/yr (Table 5.6).

The ratios of sugarcane plant parts were determined (Table 5.7 and Figure 5.8). They were separated into leaf, leaf sheath, shoot, root and stalk. The sampled were recorded, oven dried and weighted. The whole cane biomass can separate into stalk (55.82%), leaf (22.53%) leaf sheath (11.20), shoot (6.40%), and root (4.35 %), (Table 5.7). There are 33.43 % from leaf and leaf sheath and 10.75 % from root system remain in field (Figure 5.8). If this biomass is assumed that they are not subject to burning, they will be incorporated to the soil and increased organic matter. Some parts of nutrients will return to soil by decomposition of residue and release nutrients to soil to maintain soil fertility. Totally, 44.18 % from sugarcane residue and root system was input into sugarcane soil (Table 5.7).

C budget in sugarcane yield estimated the product and waste materials. Total C budget is 5.62 ton C/ha or 33% of total C. Total C budget in residue and root biomass is 11.43 ton C/ha or 67 % of total C. This was divided into 6.68 ton C/ha in top and leaves and 4.75 ton C/ha in root system. At this site, farmers did not burn biomass. It is assumed that all biomass left on field were incorporated to soil and to subject to decomposition in soil (Figure 5.9). The rest (fresh yield) were processed to final products such as sugar, molasses, filter cakes and bagasse.

Table 5.6 The amount of sugarcane biomass after harvested (top and leaves, shoot, root), (Error bars represent standard deviation of ten replications (*mean* \pm *S.D.*) for sugarcane biomass and 15 replications for root density).

	C concentration (g C/100 g dry weight biomass)	Quantity (ton/ha/yr)	Carbon (ton C/ha/yr)	% of sugarcane plant part
Sugarcane Biomass, <i>N</i>=10 (top and leaves)	38.83 \pm 0.03	17.20 \pm 4.0	6.68	-
Shoot, <i>N</i>=15	46.00 \pm 2.23	6.40 \pm 2.18	2.94	6.40
Root, <i>N</i>=15	41.60 \pm 0.34	4.35 \pm 1.79	1.81	4.35
Root density (g/cm ³), <i>N</i> =15		0.0029 \pm 0.0021		

Table 5.7 The amount of sugarcane plant part (Stalk, Leaf, Leaf sheath, shoot and root), (Error bars represent standard deviation of ten replications (*mean* \pm *S.D.*).

	C concentration (g C/100 g dry weight biomass)	Quantity (ton/ha/yr)	Carbon (ton C/ha/yr)	% of sugarcane plant part
Sugarcane plant part, <i>N</i> =10				
Stalk	-	55.82 \pm 3.76	-	55.82
Leaf	45.24 \pm 3.50	22.23 \pm 1.00	10.06	22.23
Leaf sheath	44.13 \pm 0.17	11.20 \pm 2.44	4.94	11.20
Shoot	46.00 \pm 2.23	6.40 \pm 2.18	2.94	6.40
Root	41.60 \pm 0.34	4.35 \pm 1.79	1.81	4.35
				<i>Total =100</i>

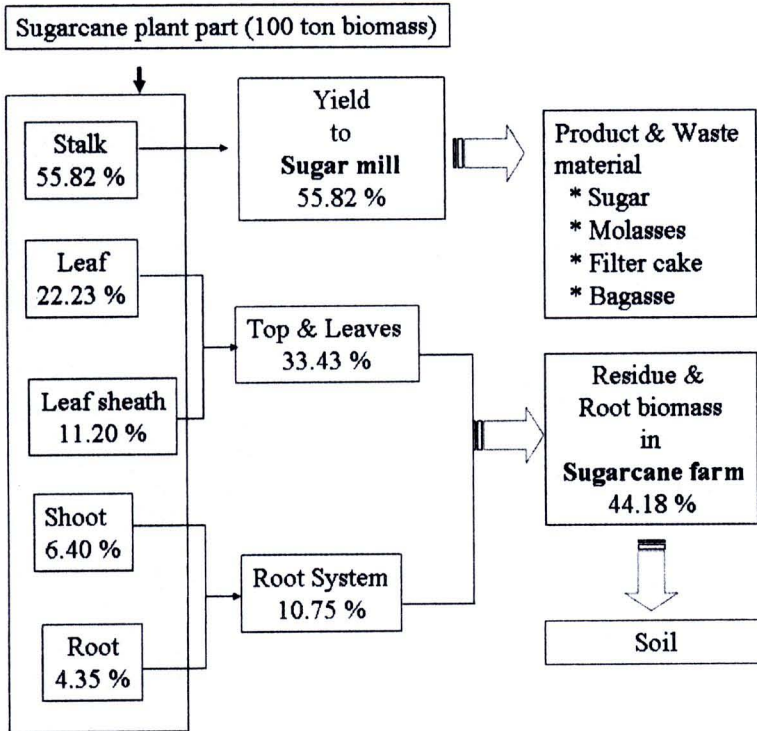


Figure 5.8 Sugarcane biomass components, processing pathways and their final products destinations.

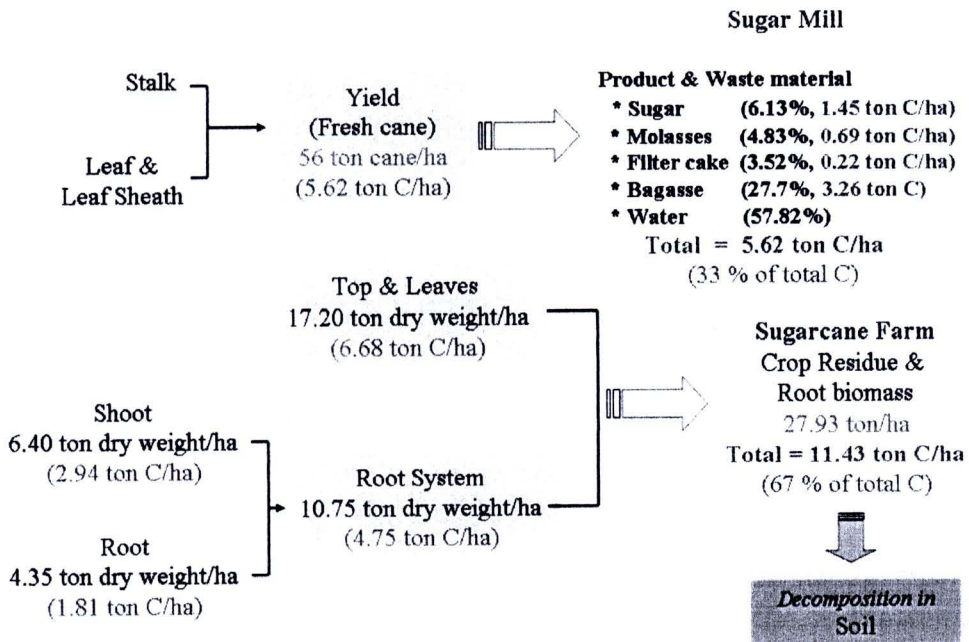


Figure 5.9 The carbon uptake in each sugarcane plant part, (Units in ton C)

It was found from a previous study of an Australian sugarcane plantation system that the C content from sugarcane residue was returned into soil system within 1 year (Robertson, 2003). Therefore, 7-12 ton/ha of trash dry matter was returned to the field

under green cane trash blanketing (approximately 10 ton/ha for every 100 ton/ha fresh cane yield). The trash contained 3-5 ton C and 28-54 kg N/ha, and had a high C:N ratio (80-120). During one year, 82-98 % of trash was decomposed. The studied show that long-term effects of converting from a burnt to about green cane trash blanketing production system suggested that, soil C and N cloud increased by 3-23 %, depending on soil and climatic factors, and that it cloud take 10-35 years for the soils to approach this new equilibrium (Robertson, 2003). The result from the Australia sugarcane plantation system suggested that incorporated sugarcane residue cloud be C and nutrient turn over into sugarcane soil system (Robertson, 2003).

Some previous studies in Thailand reported that the sugarcane residue retention cloud improved soil organic carbon and N content (Saowakon *et al.*, 2008). A similar phenomenon was previously reported by Scala *et al.* (2005) the biomass in agriculture land, and sugarcane residues (mainly leaves) had been produced by annual harvest in the rate of 17 ton of dry matter per hectare per year (7.5 ton C/ha/yr). Moreover, Peter *et al.* (2001) reported the initial residue mass about 7.7 and 19.6 ton/ha. In Australia were produced large amounts of 10 to 20 ton/ha sugarcane residue dry matter of low quality residue by C:N ratio ~ 100 (Peter *et al.*, 2001). As in literature carbon concentration of sugarcane residue is approximately 40% of dry mass (Ball-Coelho *et al.*, 1993; De Oliveria *et al.*, 1999). Others studied was reported sugarcane residues (consisting of top green and dead leaves) properties from other studied in Thailand were contained 3,483 kg C/ha and 34 kg N/ha, i.e. an average C:N ratio of 102:1, with 4.6 % lignin and 48.8 % acid detergent fiber (Saowakon *et al.*, 2008).

5.5 Carbon inputs from organic fertilizer utilization

Normally, sugarcane farmer improves soil fertility by inputting organic fertilizer before there planting. The organic fertilizer in sugarcane farm in this field is filter cake. It contains high nutrients, and the C concentration is 37.95 ± 0.42 % of dry weight. The approximately application rate was 13.13 ton of dry matter/ha/yr or 4.98 ton C/ha/yr.

Onto this plot, farmer added liquid swine manure on September, 10 during sugarcane planting. The rate was 2,083.33 liters/ha. Total Nitrogen of this manure is 1,000-1,300 mg N/liter or 2.08 to 2.708 kg N/ha (average is 2.394 kg N/ha). The amount of swine manure added was interviewed from sugarcane farmer from this plot. In addition,

the property of that manure was performed from the reviews on small and medium farm size (11-50 pigs/farm) in Thailand (Waste Utilization and Management, 2004). Thus, it can be conclude to total Nitrogen added to this farm.

5.6 Soil carbon budget

The soil organic carbon pool is the net result of soil input in the form of organic fertilizer, and incorporation of crop residues. The output includes CO₂, CH₄ fluxes and others losses. The C budget calculations indicate that there was a net loss of carbon 16.39 ton C/ha/yr from CO₂ flux. The C input by residue incorporation was 6.68 ton C/ha/yr, by root systems was 4.75 ton C/ha/yr, by organic fertilizer was 4.98 ton C/ha/yr. The net soil carbon input from the whole season was 0.02 ton C/ha/yr (Table 5.8). In addition, the estimation on global warming potential the net CO₂ equivalent from soil is net losses of 0.18 ton CO₂-eq/ha/yr (Table 5.8).

The CO₂ flux was essentially the amount of CO₂ release according to annual soil respiration (16.39 ton C/ha/yr). This value is quite large when compared to soil respiration from various systems: e.g. in cold temperate deciduous forest (8.49 ton C/ha/yr, 10.6 ton C/ha/yr) (Lee *et al.*, 2005); tropical and subtropical moist forest (8.9 to 14.5 ton C/ha/yr), in three Hawaiiin rain forests (6.5 to 8.9 ton C/ha/yr), pine plantation (9.8 to 6.9 ton C/ha/yr), respectively (Raich and Schlesinger, 1992; Raich, 1999). However, the results was in the similar range of the values reported for agriculture area when wheat straw was added at rate of 16 Mg/ha/yr in (3.39 to 16.21 ton C/ha/yr and 9.86 ton C/ha/yr in corn crop in Thailand, Duiker and Lal, (1999) and Jaiarree, (2008).

The net soil carbon balance from the whole season was the net emission of 0.02 ton C/ha/yr, partly due to the high rate of soil respiration in this study (Table 5.8). Duiker and Lal (1999) reported the similar results that the wheat straw incorporation rate of 0, 2, 4, 8 and 16 Mg/ha has resulted in a net loss of C in all treatments. The losses were highest under the low crop residue application rates and decreased with increasing residue application rate. Peterson *et al.*, 1998 reported that, under no till management in the Great Plains of the USA, in each Mg/ha, of residue returned to the soil increased soil organic carbon content by 1.52 g/kg indicating that at least part of the C added to the soil in residue was converted into soil organic carbon.

Studies on soil carbon budget in sugarcane are required to range the impact of greenhouse gases (CO_2 and CH_4) and soil fertility as mention earlier. Soil carbon budget can be estimated by integrating the amounts of net carbon supply and removal. This study the soil C quite balances from supply and removal (soil C input 0.02 ton C/ha/yr), (Table 5.8). As a result of this balance, the important factors are sugarcane residue incorporation, sugarcane biomass decomposition and organic fertilizer application. In sugarcane soil, carbon is supplied to the soil as dead roots, shoot, leaf and leaf sheath as the residue incorporation. As a result of sugarcane biomass decomposition study, the carbon in biomass will be decomposing within one year (from 3-9 months). It remained only part of lignin and holo-cellulose; the part of that difficult to decompose. Thus, crop residues was decomposed about 80 % within 1 year, the 20 % remained in debris.

Furthermore, the unburnt sugarcane biomass is an important factor to soil C input from crop residue incorporation. The rapid decomposition of sugarcane biomass will be a large soil surface respiration and it measured by soil CO_2 and CH_4 -flux and a losses of soil organic carbon. It was contributed to net soil carbon budget. In addition, the losses of soil organic carbon and soil carbon stock in sugarcane area was represented the dominate results from soil carbon losses from a long time intensive cultivation (section 4.3.2 and Mubarak *et al.* (2005). The soil organic carbon will be decreased when the area have an intensive sugarcane cultivation: especially, within two years cultivation (Silva *et al.*, 2007). From a result of Table 5.8 was presented the soil carbon budget in sugarcane area are balance and small amount of carbon input. This plots the biomass carbon from crop residue or organic fertilizer cloud not improved soil organic carbon. It may be the result of biomass rapid decomposition and this plot has been plant for 50 years. Soil organic carbon will be in the steady state as represent from the previous study (Yoneyama *et al.*, 2006). The soil organic carbon will be recuperation from longer time cultivation by sugarcane farm management. Moreover, another factor that contributes to sugarcane soil organic carbon budget, for example: sugarcane farm management, unburnt sugarcane biomass and organic fertilizer addition.



Table 5.8 Calculation of annual soil carbon budget and Global Warming Potential (2006-2007) cropping years

Segments	C Equivalent (ton C/ha/yr)		CO ₂ Equivalent (ton CO ₂ /ha/yr)	
	(a)	(b)	(a)	(b)
	<i>Soil C Input</i>	<i>Emission</i>	<i>Soil C Input</i>	<i>Emission</i>
(A) Total CO ₂ flux	-	16.39	-	60.09
(B) Total CH ₄ flux	-	0	-	-0.11
(C) Organic fertilizer (filter cake)	4.98	-	18.26	-
(D) Biomass Carbon				
- Top and leaves	6.68		24.49	
- Shoot	2.94	-	10.78	-
- Root	1.81		6.63	
Total	16.41	16.39	60.16	59.98
Net Soil Carbon (b)-(a)	-0.02		-0.18	
SOC contents (0-30 cm) (ton C ha ⁻¹)	23.22			

Negative and positive values indicate reductions and additions to atmosphere C pool, respectively.

5.7 Surveys of energy consumption and greenhouse gas emissions from sugarcane farm operation and management

This part presents the results of case study that examined energy utilization in terms of fossil fuels: diesel and gasoline and chemical utilization and subsequent greenhouse gas emissions associated with sugarcane agriculture practices in Eastern Thailand. The data used in this part of the study were collected from questionnaires. One hundred twenty five questionnaires were sent to farmers and 59 questionnaires were received (approximate to 47 % of total questionnaire). The information about the general features of farms, farm operations and energy utilization was obtained. The energy types considered include gasoline and diesel for herbicide, insecticide, irrigation, tillage and transportation. In addition, carbon emission from chemical utilization; chemical fertilizer, herbicide and insecticide application was considered.

5.7.1 Greenhouse gas emissions from fossil fuel utilization (Diesel and Gasoline) from farm operations and managements

Energy utilization from sugarcane farm management was considered. The energy utilization included energy for transportation, spray herbicides and insecticides, irrigation for water and tillage for land preparation. The data from 59 questionnaires gave the average of sugarcane production of 62.33 ± 16.9 ton/ha, with the ranges of 50 to 94 ton/ha. The farm size gave the average of 27 ± 17.7 ha, with small farm of 1.6 ha, medium farm of 24 ha and maximum farm of 96 ha. The average of transportation distance from sugarcane farm to the sugar mill was 20 ± 14.7 kilometers. This is quite similar to other researchers who collected data in other sugarcane growing regions in Thailand, which was about 25 kilometers (Khonkhen University, 2005). Therefore, the energy use for transportation for that case was 1.85 km/liter of diesel (Khonkhen University, 2005). This was 2.5 km/liter of diesel for transportation in this study.

For sugarcane farms in Thailand, irrigation is important for growing young sugarcane. Energy required for trucks and pump to spray water included diesel and gasoline oil. The application rate for water from other studies differed according to type of irrigation in use; furrow ($232.8 \text{ m}^3/\text{ha}/\text{yr}$), big gun sprinkler ($170.72 \text{ m}^3/\text{ha}/\text{yr}$), boom irrigator, center pivot ($150.72 \text{ m}^3/\text{ha}/\text{yr}$), sub surface drip ($132 \text{ m}^3/\text{ha}/\text{yr}$) (Office of the Cane and Sugar Board, 2007). In this study, the rate was 800 liters/ha. Water required for sugarcane plantation in Thailand from the literatures was reported from 240 to 960 liters/ha (Department of Agriculture, 2004).

Herbicides and insecticides are also extremely C-intensive, and their use is increasing rapidly worldwide. The energy uses in this part included: energy use for transportation for spray chemical to sugarcane plant and energy use for pump to spray herbicide and insecticide to control insect pests and weeds. In sugarcane plantation system in Thailand, sugarcane farmers spray chemical to control weeds and insect in fallow period, as well as during sugarcane growth. The amount of energy consumption depends on the methodology to spray the chemical. For example: pumping booming or manual booming, spraying time for the total work estimate and the efficiency of machine.

Carbon accounting in agriculture have been reported in many studies (Department of Agriculture, 2004), and life cycle approach were employed to examine the impacts of farm management practices on soils and total greenhouse gas emissions and reduction (Kramer *et al.*, 1999; Dyer and Desjardins, 2003; Lobb, 1989; Nebraska, 1980). Study results in the past showed that agriculture activities such as tillage, harvesting and transportation of the harvest and straw are the main sources of CO₂ emissions (Kramer *et*

al., 1999). Production and application of synthetic nitrogen fertilizers are the main cause of N₂O emission from the crop (Kramer *et al.*, 1999). Furthermore, West and Marland (2002) using a full carbon accounting analysis concept to estimate net carbon flux for three crop types in United States and demonstrated that no-till agriculture emitted less CO₂ from agriculture operations than did conventional tillage. Lal (2004) reported that tillage operations (2-20 kg CE/ha) emitted highest greenhouse gas in term of kilograms of carbon equivalent (kg CE) than that combine harvesting (6-12 kg CE/ha), drilling or seeding (2-4 kg CE/ha) and spraying chemicals (1-1.4 kg CE/ha). In the similar result, estimates of C emissions in kg CE/kg for different fertilizer nutrients were 0.9–1.8 for N, 0.1–0.3 for P₂O₅, 0.1–0.2 for K₂O and 0.03–0.23 for lime. Estimates of C emission in kg CE/kg of active ingredients of different pesticides were 6.3 for herbicides, 5.1 for insecticides and 3.9 for fungicides (Lal, 2004). Irrigation, lifting water from deep wells and using sprinkling systems, emitted 129±98 kg CE for applying 25 cm of water and 258±195 for 50 cm of water (Lal, 2004). The estimation of greenhouse gases emission from farm operation and management in this study was use median value because of wide range variation of data collection from different farm.

5.7.1.1 Diesel use

In sugarcane plants, the diesel fuel was used for tillage, irrigation, spray herbicide, spray insecticide and transportation of sugarcane yield to the sugar mill. In addition different farm size did not was gave different on the average energy demand (L/ha) for tillage, irrigation and transportation but gave different on the amount of energy demand. However, there was except for energy demand for herbicide and insecticide different farm size was gave different energy consumption. There are depends on farm management contribute to energy consumption. Herbicide and insecticide in small farm, sugarcane farmer applied herbicide and insecticide by manual booming. It means that they did not need energy to apply them. Most of the average energy demand in sugarcane plantation did not cause by farm size but farm management, the total work estimate and the efficiency of machine. There are three types of tillage: chisel plow, deep rip and strip-tillage for prepared and plant sugarcane. Energy demand for tillage practice depends on types of tillage and the amount of tillage. The sugarcane farmers have 3 to 5 times of tillage per cropping season. In addition, energy demand for transportation depends on distance from

the sugarcane farm to sugar mill and the amount of sugarcane production. There was different farm management by 59 farm or 100 % of total farm using machine for tillage and transportation. Although, 37 farms (62.71%) was used irrigation, 43 farms (72.88%) was used insecticide and small amount of herbicide was applied (4 farms or 6.78%), Table 5.9.

Thus, use of fossil fuel for tillage averaged from 146 ± 68.3 liters of diesel/ha/yr, minimum of 27.50 liters/ha/yr, maximum of 282.86 liters/ha/yr. The median is 122.92 liters of diesel/ha/yr and this was equivalent to CO₂ emission of about 0.35 ton CO₂/ha/yr (Table 5.9 and Figure 5.10). A of all types of farm operations, it was found that tillage had the highest energy use, followed by transportation, insecticide, irrigation and herbicide (122.92 liters/ha/yr (equivalent to 0.35 ton CO₂/ha/yr), 100 liters/ha (0.29 ton CO₂/ha/yr), 14.06 liters/ha/yr (0.04 ton CO₂/ha/yr), 10.94 liters/ha/yr (0.03 ton CO₂/ha/yr) and 1.65 liters/ha (0.0047 ton CO₂/ha/yr), respectively. The average for diesel fuel for one sugarcane crop was 249.57 liters/ha/yr and 0.71 ton CO₂/ha/yr (Table 5.9 and Figure 5.10).

Table 5.9 The amount of diesel fuel use and equivalent to CO₂ emissions from different management practices based on 59 questionnaires

	<i>N</i>	Diesel (liters/ha/yr)				CO ₂ equivalent (ton CO ₂ /ha/yr)		
		<i>Mean</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>
Herbicide	4	2±1.6	1.65	0.15	3.00	0.0047	0.0004	0.0086
Insecticide	43	21.2±21.3	14.06	0.47	75	0.0403	0.0013	0.2153
Irrigation	37	11±3.2	10.94	3.13	21.88	0.0300	0.0090	0.0600
Tillage	59	146±68.3	122.92	27.5	282.86	0.3500	0.0800	0.8400
Transportation	59	98±24.4	100.00	51.02	170.00	0.2872	0.1465	0.4900
Total			249.57	82.27	562.74	0.7122	0.2372	1.6139

Joao *et al.* (2007) also reported that tractor energy requirements for soil-working operations by conventional farming systems contributed to the highest energy cost (Joao *et al.*, 2007). The energy values for tillage from sugarcane plantation in this study were generally higher than those recorded from other previous studies and other crop types (chisel plow; 12.4-20.2 liters/ha, deep rip; 18.0-46.0 liters/ha and strip-tillage; 5.6-11.2 liters/ha, and total energy requirement ranged from 36.0 to 87.4 liters/ha/yr). In this study

fossil fuel use for chisel plow was 2.5 liters/ha, deep rip was 4.88 liters/ha and strip tillage was 2.5 liters/ha. Moreover, the other researchers reported energy utilization for tillage for land preparation ranged from 41.2 to 171.7 liters/ha/yr (Nebraska, 1980). There are different depend on total work estimate and machine efficiency.

5.7.1.2 Gasoline fuel use

Gasoline (Benzene 91) was used to spray herbicides and insecticides and for irrigation (Table 5.10). The highest use was to spray insecticide (15.63 liters/ha/yr) and lowest for spray of herbicide (2.8 liters/ha/yr). Total gasoline used was 22.34 liters/ha/yr. The average gasoline fuel use from herbicide, insecticide and irrigation was 2.8, 15.63 and 3.91 liters/ha/yr, respectively (Table 5.10 and Figure 5.10). Therefore, CO₂ equivalent to emission from gasoline fuel use from herbicide, insecticide and irrigation was 0.0067, 0.0375 and 0.0094 ton CO₂ equivalent/ha/yr, respectively (Table 5.10 and Figure 5.10). Therefore, energy consumption for field spraying operations of herbicide from the other studied was reported as 0.0017 ton CO₂/ha/yr (Lobb, 1989).

Table 5.10 Quantity of fuel (Benzene 91) used in different sugarcane management base on 59 questionnaires and equivalent to CO₂ emission

	Gasoline (liter/ha/yr)					CO ₂ equivalent (ton CO ₂ /ha/yr)		
	<i>N</i>	<i>Mean</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>
Herbicide	4	3±2.6	2.80	0.25	5.00	0.0067	0.0006	0.0119
Insecticide	43	30±29.5	15.63	0.78	93.75	0.0375	0.0019	0.2247
Irrigation	37	5±2.4	3.91	3.91	15.63	0.0094	0.0094	0.0375
Tillage	-	-	-	-	-	-	-	-
Transportation	-	-	-	-	-	-	-	-
Total			22.34	4.94	114.38	0.0536	0.0119	0.2741

5.7.1.3 Total CO₂ emission from energy consumption of farm operation and management

Average gasoline use was 22.34 liters/ha/yr or 0.0536 ton CO₂/ha/yr and average diesel was 249.57 liters/ha/yr or 0.7122 ton CO₂/ha/yr equivalent (Table 5.9, 5.10 and Figure 5.10). The energy use and CO₂ emissions was highest in the part of tillage practice (46% of total energy use and CO₂ emissions from gasoline and diesel use in farm operation) followed by transportation (38%), insecticide (10%), irrigation (5%) and herbicide (1%) of the total energy consumption from farm operations, respectively (Figure 5.10). This was contributed to greenhouse gases emissions.

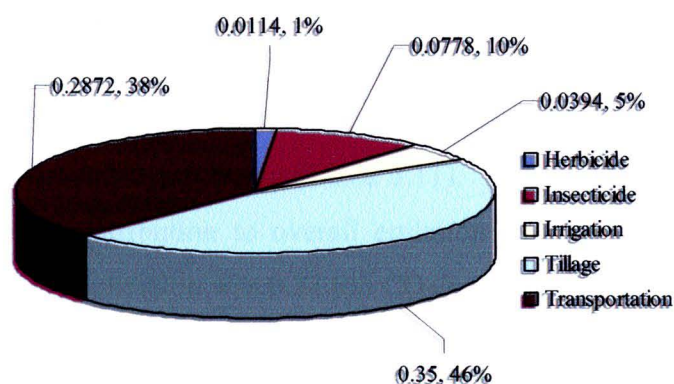


Figure 5.10 Total CO₂ emission equivalents from sugarcane farm management combining between diesel and gasoline fuel consumption

5.7.2 Carbon and greenhouse gas emissions from chemical utilization (fertilizer, herbicide and insecticide)

5.7.2.1 Chemical Fertilizers

The information collected from the surveys reveals that sugarcane farmers used a variety of chemical fertilizers, resulting in ranges of energy required for production of fertilizers. In the present study, raw data from questionnaire chemical fertilizer application rate was approximately 50-100 kg/rai/yr or 312.5-625 kg/ha/yr (6.25 rai = 1 ha). The farmer applied chemical fertilizer at 2-3 times throughout the whole cropping year; before and after sugarcane planting. The other fertilizer type like organic fertilizer; farmyard, sugarcane farmer were applied on the soil surface after grow sugarcane. The application rate of 20 ton/ha/yr, there have 35 farms or 59 % of the total farms. The chemical fertilizer types applied were; 21-4-21, 6-14-12, 15-15-15, 15-7-8, 46-0-0, 20-20-0, 40-0-0, 13-13-21, 16-8-8, 15-8-8, 21-0-0, 21-8-8, 16-16-16 and others. The most chemical fertilizer types is

15-15-15 they applied 59 farms or 100% of total farm. Moreover urea was applied at the same rate 50-100 kg/rai/yr or 312.5-625 kg/ha/yr, it has 4 farms or 6.78 % of total farm. The average urea application was 323 ± 137.6 kg/ha/yr (Table 5.11). In the rate of chemical fertilizer, Nitrogen gave a higher value than other Potassium and Phosphorus because sugarcane need more nitrogen fertilizer supply.

The data included the quantity of chemical fertilizers between N, P₂O₅ and K₂O and GHG emission (Table 5.11). The average of nitrogen, phosphorus and potassium use was 199 ± 203.6 kg N/ha/yr, 149 ± 162.2 kg P₂O₅/ha/yr and 152 ± 165.2 kg K₂O /ha/yr respectively. In addition, the mean of nitrogen, phosphorus and potassium use was 140.63 kg N/ha/yr, 93.75 kg P₂O₅ /ha/yr and 93.75 kg K₂O /ha/yr. Net CO₂ emission from chemical fertilizer was 0.29, 0.06 and 0.04 ton CO₂/ha/yr for Nitrogen (N), phosphorus (P₂O₅) and potassium (K₂O), respectively (Table 5.11). In addition, N chemical fertilizer represented the highest contribution to overall emission from chemical fertilizers. The CO₂ emission from urea application was 0.32 ton CO₂/ha/yr (Table 5.11).

The nitrogen application to the field on average has resulted in the emissions of N₂O of about 1.797 kg N₂O/ha/yr and equivalent to 0.557 ton CO₂/ha/yr. Urea application alone has contributed to 0.32 ton CO₂/ha/yr equivalent. Totally, nitrogen application in farm and urea application emitted 0.877 ton CO₂/ha/yr (Table 5.12).

Table 5.11 Fertilizer use and equivalent to CO₂ emission from chemical fertilizer base on the information from 59 questionnaires, the emission from chemical production

	<i>N</i>	The amount of chemical fertilizer (kg/ha/yr)				CO ₂ equivalent (ton CO ₂ /ha/yr)		
		<i>Mean</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>
Nitrogen (N)	59	199±203.6	140.63	18.75	343.75	0.29	0.06	1.08
Phosphorus (P ₂ O ₅)	59	149±162.2	93.75	0	281.25	0.06	0	0.17
Potassium (K ₂ O)	59	152±165.2	93.75	0	281.25	0.04	0	0.12
<i>Subtotal</i>			328.13			0.39		
Urea	4	323±137.6	359.40	143.8	431.3	0.32	0.21	0.32
<i>Total</i>			687.53			0.71		

5.7.2.2 N₂O emissions from soils

Nitrous oxide (N₂O) is produced naturally in soils by the processes of nitrification and denitrification. Nitrification is the aerobic microbial oxidation of ammonium to nitrate, and denitrification is the anaerobic microbial reduction of nitrate to nitrogen gas (N₂). Nitrous oxide is a gaseous intermediate in the reaction sequence of denitrification and by product of nitrification that leaks from microbial cell into the soil and ultimately into the atmosphere. One of the main controlling factors in this reaction is the availability of inorganic N in soils.

N₂O emissions from sugarcane soil can be estimated from both direct emission (synthetic fertilizer, manure application and organic fertilizer) and indirect emission (atmospheric deposition of NO_x and NH₃ and leaching and runoff). Based on the amount of N inputs and emission factors from IPCC 2006 Guideline, the N₂O emission from direct emission was 1.616 kg N₂O/ha/yr, equivalent to 0.501 ton CO₂/ha/yr. The N₂O from indirect emission was 0.181 kg N₂O/ha/yr, equivalent to 0.056 ton CO₂ /ha/yr. Totally, N₂O emission from both sources is 1.797 kg N₂O/ha/yr, equivalent to 0.557 ton CO₂ /ha/yr (Table 5.12).

Table 5.12 Direct and indirect N₂O emission from agriculture soil, the emission from chemical fertilizer and organic fertilizer utilization

Categories	N ₂ O (kg N ₂ O/ha/yr)			CO ₂ equivalent (ton CO ₂ /ha/yr)		
	<i>Median</i>	<i>Min</i>	<i>Max</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>
<i>Direct Emission</i>						
a) Synthetic N fertilizer	1.5	0	5.4	0.465	0	1.674
b) Liquid swine manure	0.038	0.003	0.043	0.012	0.001	0.013
c) Organic fertilizer	0.078	0.077	0.079	0.024	0.024	0.024
Subtotal 1	1.616	0.08	5.522	0.501	0.025	1.711
<i>Indirect Emission</i>						
a) Emission from atmospheric deposition of NO _x and NH ₃	0.155	0.007	0.549	0.048	0.002	0.170
b) Emission from leaching and runoff	0.026	0.005	0.083	0.008	0.002	0.026
Subtotal 2	0.181	0.012	0.632	0.056	0.004	0.196
Total	1.797	0.092	6.154	0.557	0.029	1.907

Table 5.13 N₂O emissions from Nitrogen Fertilizer and CO₂ emissions from Urea application and equivalent to CO₂ emission

Descriptions	Unit	Median	Min	Max
(1) N ₂ O emission from direct emission	kg N ₂ O/ha/yr	1.616	0.08	5.522
(2) N ₂ O emission, equivalent to CO ₂ Emission-direct emission	ton CO ₂ /ha/yr	0.501	0.025	1.711
(3) N ₂ O emission from indirect emission	kg N ₂ O/ha/yr	0.181	0.012	0.632
(4) N ₂ O emission, equivalent to CO ₂ Emission-indirect emission	ton CO ₂ /ha/yr	0.056	0.004	0.196
(5) Urea application, equivalent to CO ₂ Emission	ton CO ₂ /ha/yr	0.320	0.210	0.320
Total (2)+(4)+(5)	ton CO ₂ /ha/yr	0.877	0.239	2.227

5.7.2.3 Herbicides and Insecticides

Although, there was a small number of sugarcane farmer using the herbicide to control weeds, a large amount of sugarcane farmers used insecticides (81 % of total uses) to control insects and pests (Table 5.14). Common herbicide and insecticide applied included ametryne, atrazine, paraquat and 2, 4-D. The average herbicide and insecticide application from 59 case studies were 18±25.9 kg/ha/yr and 19±15.8 kg/ha/yr. The median herbicide and insecticide application from 59 case studies were 6.25 kg/ha/yr (0.028 ton CO₂/ha/yr) and 12.50 kg/ha/yr (0.057 ton CO₂/ha/yr), (Table 5.14).

Table 5.14 CO₂ equivalent from herbicide, insecticide application

	The amount of chemical (kg/ha/yr)					CO ₂ equivalent (ton CO ₂ /ha/yr)		
	<i>N</i>	<i>Mean</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>
Herbicide	4	18±25.9	6.25	1.25	56.25	0.028	0.028	0.248
Insecticide	43	19±15.8	12.50	0	56.25	0.057	0	0.258
Total			18.75			0.085		

5.7.2.4 Sugarcane Biomass Burning

Normally, sugarcane farmer have burned biomass before and after harvest. Burning of cane residues either before or after sugarcane harvest is widely practiced in many tropical countries. Farmers' burn sugarcane to reduce the amount of leaf extraneous material, including stalk tops and dead leaves delivered with the cane to the factories for

processing and to control pests. Additionally, sugarcane burning facilitates manual harvesting thus reducing labor and production costs. Residue combustion is a source of particulate and gaseous (CO_2 , NO , NO_2 and N_2O) emissions to the atmosphere and emitted some pollution like ash and dust. Moreover, biomass burning cloud losses of nutrient to soil.

The burning of sugarcane biomass was investigated in this study. Pre-harvest burning in this region was occurred because farmers need to reduce cost for labor to harvest. It is dirty and reduced the quality of sugar. On the other hand, sugarcane biomass burning after harvest was for easier land preparation in the next cropping season. From the surveys, it was found that the burned area covered 68.49 % and un-burned area covered 31.50 % of the total sugarcane area (Table 5.15). The pre-harvest burning covered 30.82 % and post harvest burning covered 37.67 % of the total area (Table 5.15). In addition the comparison between data from the interviews and the sugarcane yield from sugar mill factory in Eastern region, it was found that there was similar data on burned and unburned cane (Table 5.16).

Based on the biomass per ha, and the area fraction that were burned, it is estimated that biomass burning emitted greenhouse gases in term of CH_4 and N_2O of about 0.0913 kg $\text{CH}_4/\text{ha}/\text{yr}$ and N_2O 0.0024 kg $\text{N}_2\text{O}/\text{ha}/\text{yr}$, respectively (Table 5.16). In term of CO_2 equivalence, CH_4 emission of 1.92 kg $\text{CO}_2\text{-eq}/\text{ha}/\text{yr}$ and N_2O of 0.74 kg $\text{CO}_2\text{-eq}/\text{ha}/\text{yr}$. The totally of greenhouse gas emission in terms of CO_2 equivalent is 2.66 kg $\text{CO}_2\text{-eq}/\text{ha}/\text{yr}$ (Table 5.16). CO_2 emission did not account in this emission because CO_2 cloud be recovered in the system by photosynthesis process when plant are re-growth. The whole budget was accounted for CO_2 and CH_4 to 0.019 ton C/ha/yr.

Table 5.15 The percentage of sugarcane biomass burning and un-burnt data from 59 questionnaires

	Percentage of sugarcane burn and un-burn area (%)			Eastern Thailand (2003/04 to 2007/08 production years)
	Total	Pre-harvest	Post-harvest	
Burn	68.49	30.82	37.67	60.9
Un-burn	31.50	-	-	38.57

Table 5.16 Greenhouse gases emissions (CH₄ and N₂O emissions) from biomass burning, represented to CO₂ equivalent

Emission from biomass burning	Unit	Quantity
CO ₂	ton CO ₂ /ha/yr	0.051
CH ₄	kg CH ₄ /ha/yr	0.091
N ₂ O	kg N ₂ O/ha/yr	0.002
CH ₄	kg CO ₂ -eq/ha/yr	1.92
N ₂ O	kg CO ₂ -eq/ha/yr	0.74
CO ₂	ton C/ha/yr	0.014
CH ₄	ton C/ha/yr	0.005
Total biomass	ton/yr	62.40

5.7.3 Total greenhouse gases emission from farm operations and managements

The total greenhouse gas emissions were estimated from the information presented up to this point. The results are presented in Table 5.17 and Table 5.18. The highest GHG emission was occurred from fertilizer utilization (41.5%) followed by energy utilization from farm operation (35.9 %), fertilizer production (18.4 %), herbicide and insecticide applications (4.2 %) and biomass burning (0.1 %), respectively. The average gasoline use in one year sugarcane cropping system was 22.34 liters/ha/yr or 0.05 ton CO₂/ha/yr and average diesel use was 249.57 liters/ha/yr or 0.71 ton CO₂/ha/yr equivalent. In addition, the use of chemical utilization emitted greenhouse gas equivalent to 0.88 ton CO₂/ha/yr. In addition, biomass burning emitted 0.003 ton CO₂-eq/ha/yr (Included N₂O and CH₄ emissions). Total greenhouse emission in term of CO₂ equivalent from sugarcane plantation combined between energy consumption, chemical production and utilization application and biomass burning was equivalent to 2.12 ton CO₂ /ha/yr (Table 5.17).

Comparing between energy utilization and greenhouse gases emission from farm operation and fertilizer and herbicide manufacture, the largest GHGs emission come from chemical fertilizer and smallest from biomass burning (Table 5.17, Table 5.18). This was quite similar to the results from the previous studies in central region of Thailand. There were reported in sugarcane farming by the largest contribution energy inputs comes form energy for fertilizers and herbicide manufacture at 45.6% of total energy input, and the

smallest due to diesel fuel used for farm machinery (10.7%) (Nguyen *et al*, 2008). On the chemical utilization in this study the large portion emission come form nitrogen fertilizers. It contributed about 40 % of total emission from sugarcane farm operations and managements (Table 5.17). Thus, greenhouse gas emissions from sugarcane cultivation practices and farm operation in Eastern region were estimated from questionnaires and surveys in the production year 2006/2007. The average gasoline use was 22.34 liters/ha/yr or 0.0536 ton CO₂/ha/yr, or 2.4 % of the emissions combined between energy use and chemical utilization (Table 5.10 and Table 5.17). The average diesel use was 249.57 liters/ha/yr or 0.712 ton CO₂/ha/yr, or 33.5 % of the total emission between energy use and chemical utilization (Table 5.9 and Table 5.17). The use of energy for tillage practice contributed the highest portion of energy input in sugarcane plantation system and thus the main sources of CO₂ emissions. Totally CO₂ emission for sugarcane plantation combined between energy use and chemical utilization application and biomass burning was 2.12 ton CO₂ /ha/yr (Table 5.17). Calculated base on 56 ton cane/ha and 1 ton cane can be produce 93.23 kg of sugar total CO₂ equivalent were appeared of 37.91 kg CO₂/ton cane and 0.407 kg CO₂/kg sugar (Table 5.17).

Hence, over the whole area of sugarcane production in the Eastern region, CO₂ emitted 148,546 ton CO₂ equivalent per year (from (2.12 ton CO₂/ha/yr) * (70,069 ha); the sugarcane area in Eastern Thailand).



Table 5.17 GHG emissions equivalent to CO₂ emission from farm operation and management (Include sugarcane biomass burning)

Emission sources	CO ₂ equivalent			% of total
	(ton CO ₂ /ha)	(kg CO ₂ /ton cane)*	(kg CO ₂ /kg sugar)**	
Gasoline fuel for farm operation	0.05	0.89	0.010	2.4
Diesel fuel for farm operation	0.71	12.68	0.136	33.5
Fertilizer production				
- Nitrogen (N)	0.29	5.18	0.056	13.7
- Phosphorus (P ₂ O ₅)	0.06	1.07	0.011	2.8
- Potassium (K ₂ O)	0.04	0.71	0.008	1.9
Subtotal	0.39	6.96	0.075	18.4
Fertilizer utilization				
- N ₂ O Direct emission	0.50	8.93	0.096	23.6
- N ₂ O Indirect emission	0.06	1.07	0.011	2.8
- Urea applicaion	0.32	5.71	0.061	15.1
Subtotal	0.88	15.71	0.169	41.5
Herbicide	0.03	0.54	0.006	1.4
Insecticide	0.06	1.07	0.011	2.8
Biomass burning (N ₂ O,CH ₄)	0.003	0.05	0.001	0.1
Total	2.12	37.91	0.407	100

Table 5.18 GHG emissions equivalent to CO₂ emission from farm operation and management (Exclude sugarcane biomass burning)

Emission sources	CO ₂ equivalent			% of total
	(ton CO ₂ /ha)	(kg CO ₂ /ton cane)*	(kg CO ₂ /kg sugar)**	
Gasoline fuel for farm operation	0.05	0.89	0.010	2.4
Diesel fuel for farm operation	0.71	12.68	0.136	33.5
Fertilizer production				
- Nitrogen (N)	0.29	5.18	0.056	13.7
- Phosphorus (P ₂ O ₅)	0.06	1.07	0.011	2.8
- Potassium (K ₂ O)	0.04	0.71	0.008	1.9
Subtotal	0.39	6.96	0.075	18.4
Fertilizer utilization				
- N ₂ O Direct emission	0.50	8.93	0.096	23.6
- N ₂ O Indirect emission	0.06	1.07	0.011	2.8
- Urea applicaion	0.32	5.71	0.061	15.1
Subtotal	0.88	15.71	0.169	41.5
Herbicide	0.03	0.54	0.006	1.4
Insecticide	0.06	1.07	0.011	2.8
Total	2.12	37.86	0.406	100

* Calculate base on 56 ton cane yield/ha

** Calculate base on 1 ton cane can produce 93.23 kg sugar

5.8 Full carbon accounting from sugarcane plantation

The carbon accounting from sugarcane plantation activities in this region is net C emissions about 0.58 ton C/ha/yr (include biomass burning) and 0.56 ton C/ha/yr (do not include biomass burning). The budget that include sugarcane biomass burning was divided into C input from soil about 0.02 ton CE/ha/yr and C emission about 0.60 ton CE/ha/yr from farm management (Figure 5.11, 5.12 and Table 5.23). In the part of soil carbon, the highest portion of soil carbon the emission from CO₂-C flux (16.39 ton CE/ha/yr, 49.07% of total carbon budget). Moreover, this was quite balance between C emission and C addition in term of crop residues, root and organic fertilizer. In the part of C emission from farm management and chemical utilization; chemical fertilizer, herbicide and insecticide show highest portion of C emission followed by farm machine and biomass burning (Figure 5.11 and Table 5.23).

Moreover, totaled carbon input in terms of sugarcane biomass, organic fertilizer and root system is 16.41 ton CE/ha/yr equivalent. Then, carbon output in term of CO₂ flux, CH₄ flux, farm machine, chemical utilization and sugarcane biomass burning is 16.99 ton CE/ha/yr. Thus, the net carbon in sugarcane plantation systems is emitted about 0.58 ton CE/ha/yr (Table 5.23). There are including emission from biomass burning.

In Table 5.23 calculated base on 56 ton cane/ha (average yield from Eastern region from 2003/2008 production year), it was found that the carbon equivalent in sugarcane plantation emitted about 10.35 kg C/ton cane. Therefore, calculated base on sugar product by 1 ton cane can produce 93.23 kg of sugar (Table 6.2, data from 4 sugar mills in Eastern region). The net carbon from sugarcane plantation is emitted 111.02 kg C/ton sugar.

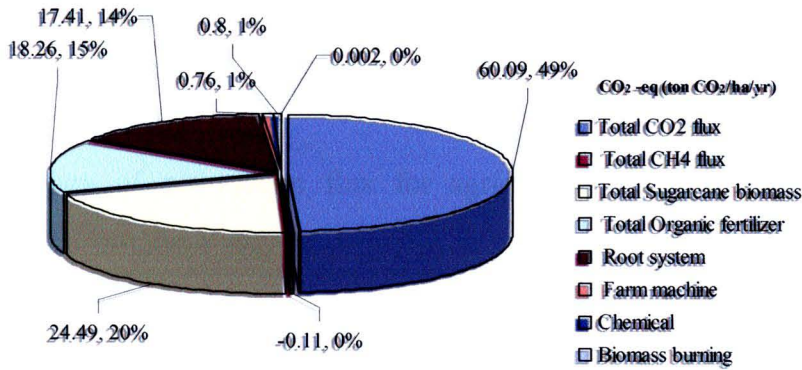


Figure 5.11 Annual C budgets in sugarcane plantation activities

5.9 GHG emission and full carbon accounting comparison from the previous studies

Up to this point, when compare the emission from farm operation and management from this study with other previous studies, the emission from this study with in the range of the previous studies (Khonkhen University, (2005); Department of Agriculture, (2004); West and Marland, (2002); Lal, (2004); Joao *et al.* (2007); Nebraska, (1980)). These include greenhouse emission from energy utilization, chemical fertilizer, herbicide and insecticide. In the biomass burning, sugarcane gave large amount of biomass burning when compare between sugarcane biomass and other crop. Net C emission from sugarcane plant from this study was larger than other crop type in US. and smaller than corn crop in Thailand (Table 5.19). However, the different net C budget was a different on farm management and the source of data obtain to estimate net C on that crop type. The example of net C emission from corn crop gave a value of 305.19 kg C/ha (conventional tillage), 329.31 (minimum tillage) smaller than sugarcane plantation in this study, through, net C emission about 583 kg C/ha (West T.O., 2008).

The results of this study were compared to those of other studies of sugarcane area in Thailand (Table 5.20). The data from this study was in the similar range of data about farm management from the previous study. However, this project study have more details include in the estimation for example; this project study added more data about estimate C emission and reduction from soil, diesel and gasoline utilization for herbicide, insecticide, irrigation, tillage and greenhouse gases from biomass burning. The previous studies include only one data about diesel fuel use from transportation (Table 5.20). Moreover, the comparison between C footprint; the CO₂ equivalent by life cycle of product, sugarcane

plantation gave smaller emission than other crop types for example rice and pine apple (Table 5.21).

Table 5.19 Summary of net carbon flux for agriculture from previous studied and sugarcane plantation from this study

Plots	This study	Jaiarree, 2008	Jaiarree, 2008	West & Marland , 2002	West & Marland , 2002
	Sugarcane	Corn, Thailand CHC ^a	Corn, Thailand CHR ^b	Corn, Soybean, Wheat, US. ^c	Corn, Soybean, Wheat, US. ^d
Soil C stocks (0-30 cm)	23.22	41.55	26.47		
C emission from soil	+16.39	+10.14	+9.86		
C from biomass (in crop type)	-6.68	-4.76	-3.20		
C from compost (<i>Canavalia spp.</i>)	-	-0.99	-0.61		
C from compost		-8.62	-5.17		
C organic fertilizer	-4.98	-	-		
C root system	-4.75	-	-		
C emission from machinery	+0.21	+0.14	+0.13	+0.069	+ 0.023
C emissions from agriculture input	+0.39	+1.59	+1.06	+0.099	+0.114
Net C flux	+0.58	-2.50	+2.07	+0.168	+0.137

^a addition compost 50 ton/ha/yr

^b addition compost 30 ton/ha/yr

^c Conventional tillage

^d No tillage

Table 5.20 Direct materials, energy-related and chemical utilization for sugarcane production

Segment	Unit	This study	References	
			Thai sugarcane ^a	Other
Sugarcane	tones/ha	62.40	57	56 ^b
Cane trash	tones/ha	17.2	11.4	7-12 ^c
Root biomass	tones/ha	10.35	-	3.9-7.9 ^d
Organic fertilizer input	ton C/ha	4.98	-	
- Filter cake	tones/ha	13.13	-	
- Liquid swine manure	mg/L	1,000- 1,300	-	
;TKN		2,083	-	
- Liquid swine manure	L/ha		-	
Water apply to sugarcane farm	L/ha	800		240-960 ^e
Fertilizer	kg/ha			
- Nitrogen as N		140	128	61.75 ^g
- Phosphorus		93	37	37.05 ^g
- Potassium		93	28	98.8 ^g
- Urea		359		156.25 ^h
Herbicide	kg/ha	6	12.1	
Insecticide	kg/ha	12.5	-	
Diesel used for farm machinery	L/ha		63	
- Herbicide		1.6		
- Insecticide		14		
- Irrigation		11		
- Tillage		123		36 -87.4 ^f
Diesel used for transportation	L/ha	100	113	
	km/L	2.5		1.85 ^g
Gasoline used for farm machinery	L/ha		-	
- Herbicide		2.8		
- Insecticide		15.6		
- Irrigation		3.9		

^a Nguyen., (2007a)^b Based on calculated from Eastern Thailand 2003/04-2007/08 production year^c Robertson (2003)^d Smith, *et al.* (2005)^g Khonkhen University. (2005)^e Department of Agriculture, (2004)^f Joao, *et al.* (2007)^h Macedo *et al.* (2004)

Table 5.21 Carbon footprint in agriculture and food product

Product	Unit	C footprint	Remark	References
Sugarcane *	kg CO ₂ -eq/ton cane	39.91	The footprint in sugarcane cultivation	This study
Sugar *	kg CO ₂ -eq/kg sugar	0.407	The footprint in sugarcane cultivation	This study
Sugar	kg CO ₂ -eq/kg raw sugar	0.233	The footprints in Mauritius: include emission from packaging and transport	Ramjeawon, 2004
Sugar	kg CO ₂ -eq/kg sugar	0.04	The footprint from emission in sugar mill, sugar Mitre Phol band, Thailand	Mitr Phol Group, 2010
Sugar beet	kg CO ₂ -eq/kg sugar	116-181	The footprint include emission from farm and factory	Tzilivakis <i>et al.</i> 2005 , Defra 2006
Sugar beet	kg CO ₂ -eq/kg sugar	0.5	Sugar silver spoon band include farm, transport, factory, packaging and distribution vs. disposal	Silverpool, 2010
Rice	kg CO ₂ -eq/kg rice	4.4	The footprint in rice cultivation	TRF, 2010
Pine apple	kg CO ₂ -eq/kg fresh	11	Fresh pine apple, when air freighted to Europe	Plassmann, K., 2009
Pine apple	kg CO ₂ -eq/kg fresh	1.2	Fresh pine apple, when they are process into jam and shipped to Europe	Plassmann, K., 2009
Potato	kg CO ₂ -eq/kg potato	0.218	Cradle to pack house, include the emission from potato cultivation to storage & packing	Brandao, M., 2008
Fruit drink-Innocent band	kg CO ₂ -eq/ bottle 250 ml/bottle	0.273	C footprint include distribution, smooth, manufacturing, transport, packing, growing	Mungkung, R. 2009

* This study result

Table 5.22 Calculation of annual carbon budget in sugarcane plantation (Include sugarcane biomass burning)

Segments	C equivalent (ton C/ha/yr)	CO ₂ equivalent (ton CO ₂ /ha/yr)	% of total (C equivalent)
(1) Soil carbon			
(A) Total CO ₂ -C flux	16.39	60.09	49.94
(B) Total CH ₄ -C flux	0	-0.11	0.00
(C) Total Sugarcane biomass	6.68	24.49	20.35
(D) Total Organic fertilizer	4.98	18.26	15.17
(E) Root system	4.75	17.41	14.47
(A+B)-(C+D+E)	-0.02	-0.18	99.93
(2) Farm management			
(E) Farm Machine			
- Tillage	0.095	0.35	0.29
- Transportation	0.079	0.29	0.24
- Irrigation	0.011	0.04	0.03
- Herbicide	0.003	0.01	0.01
- Insecticide	0.022	0.08	0.07
<i>Subtotal</i>	0.21	0.77	0.64
(F) Chemical fertilizer production			
- Nitrogen (N)	0.079	0.29	0.24
- Phosphorus (P ₂ O ₅)	0.016	0.06	0.05
- Potassium (K ₂ O)	0.011	0.04	0.03
<i>Subtotal</i>	0.11	0.39	0.32
(G) Chemical fertilizer utilization			
- N ₂ O Direct emission	0.136	0.50	0.41
- N ₂ O Indirect emission	0.016	0.06	0.05
- Urea	0.087	0.32	0.27
<i>Subtotal</i>	0.24	0.88	0.73
(H) Chemical; Herbicide, Insecticide			
- Herbicide	0.008	0.03	0.02
- Insecticide	0.016	0.06	0.05

<i>Subtotal</i>	0.024	0.09	0.07
(I) Biomass Burning	0.019*	0.003**	0.06
(E+F+G+H+I)	0.603	2.133	
Net carbon in agriculture (2)+(1)	0.583	1.953	

* Include CH₄ and CO₂

** Include CH₄ and N₂O

Table 5.23 Calculation of annual carbon budget in sugarcane plantation in term of carbon equivalent (Include biomass burning)

Segments	Carbon equivalent			% of total
	(ton C/ha/yr)	(kg C/ton cane)*	(kg C/ton sugar)**	
<i>1. Emission</i>				
(A) Soil CO ₂ -C flux	16.39	292.68	3139.33	49.07
(B) Soil CH ₄ -C flux	0	0.00	0	0.00
(C) Energy utilization from farm operation and management	0.21	3.75	40.22	0.63
(D) Chemical fertilizer	0.35	6.25	67.04	1.05
(E) Chemical herbicide, insecticide	0.02	0.36	3.86	0.06
(F) Biomass burning	0.02	0.36	3.86	0.06
<i>Subtotal</i>	<i>16.99</i>	<i>303.39</i>	<i>3254.21</i>	<i>50.87</i>
<i>2. Input</i>				
(A) Total sugarcane biomass	6.68	119.29	1279.52	20.00
(B) Total organic fertilizer	4.98	88.93	953.88	14.91
(C) Root system	4.75	84.82	909.79	14.22
<i>Subtotal</i>	<i>16.41</i>	<i>293.04</i>	<i>3143.19</i>	<i>49.13</i>
Net carbon in agriculture (1)-(2)	0.58	10.35	111.02	100

* Calculate base on 56 ton cane yield/ha

** Calculate base on 1 ton cane can be produce 93.23 kg of sugar

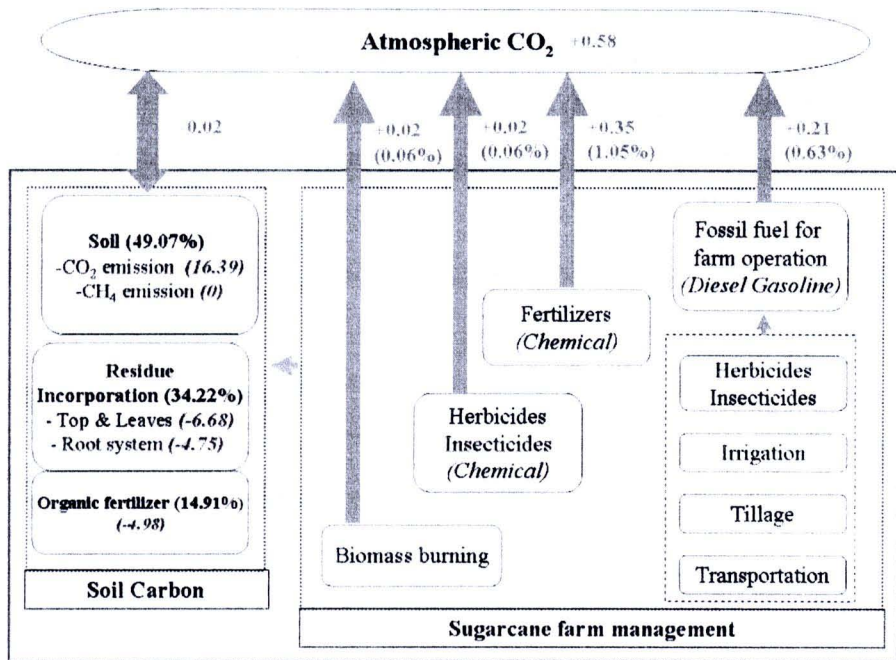


Figure 5.12 Annual carbon fluxes in sugarcane plantation system. Values embedded in arrows measure rates of flow; other values measure changes in stocks. Rates of flow between the atmospheres and biosphere (crop/soil pool) are inherent in the change in soil carbon stock. Units in ton CE/ha/yr.

5.10 Summary of the results

The results of this study show that sugarcane biomass decomposition had the fastest decomposition rates on leaf sheaths and lowest on roots. The different soil depths gave a significant different in decomposition rates. Sugarcane biomass was decomposing within 1 year: 80% was decompose in the portion that easily to decompose and 20% remain will take long time to decompose. The rapid decomposition will contribute to soil surface respiration. In the part of biomass C, the residue incorporation and root biomass input soil C of 11.43 ton CE/ha/yr or 34.22% of total soil carbon budget. In addition, to promote to use organic fertilizer in sugarcane farm, it can be C input of 4.98 ton CE/ha/yr or 14.91% of total soil carbon budget.

Annual soil carbon in this plot of the study is sequestering about 0.02 ton CE/ha/yr. There are quite balance between input and output from soil. The balance from soil C input was occurred from crop residue retention and organic fertilizer application. This plot soil organic carbon from crop residue or organic fertilizer cloud not improve soil organic

carbon, it may be the result of this plot has been plant for more than 50 years. Soil organic carbon will be in the steady state, it was similar pattern result from the previous studies.

In addition the whole carbon budget in sugarcane farm is emitted of 0.58 CE/ha/yr into the atmosphere. It combined between soil carbon and GHG emission from sugarcane farm operation and management. On the part of GHG emission from farm operation and management; chemical utilization emitted largest portion of GHG emissions followed by fossil fuel utilization, herbicide and insecticide application and biomass burning. In the part of GHG emission from chemical fertilizer emitted about 60% of total GHG emission from farm operation and management, especially, Nitrogen fertilizer. In addition, fossil fuel utilization the tillage practice gives a highest portion of fossil fuel utilization and GHG emission.

Results from this experiment suggest that there would be some possibilities to reduce GHG emission from sugarcane plantation activities. In sugarcane soil, the residue incorporate can be soil carbon turnover and get balance between soil C input and output. The reduce GHG emission from sugarcane farm operation and management the government can be promote to reduce greenhouse gases emission by farm management. Because of, there are not different between the small, medium and maximum farm on an average of energy demand and chemical utilization but different on the amount of energy demand and chemical consumption on the different farm size. Hence, the first option government cloud promotes to manage in the large farm. These cloud be promote to reduce tillage and chemical fertilizer utilization, reduce or change the amount of herbicide and insecticide utilization to organic substance, these may be an option to GHG emission reduction from sugarcane plantation system.