Carbon Use Efficiency of the First Ratoon Cane by Eddy Covariance Technique

Tiwa Pakoktom, Nongpat Chaichana, Jessada Phattaralerphong, and Jate Sathornkich

Abstract—**The propose of this study was to evaluate CO_2 flux and accumulative CO_2 absorbance of the first ratoon cane by using Eddy Covariance Technique. First ratoon cane was produced at Cane and Sugar Industry Promotion Center, Kanchanaburi province, from June 2010 to April 2011. From the results, the CO_2 flux was fluctuated from -2.4 to 2.8 $mgCO_2m^{-2}s^{-1}$. The negative values showed in the day time and it means CO_2 was absorbed by plant via photosynthesis. On the other hand the positive values means CO_2 was emitted by plant and soil respiration in night time. Different CO_2 flux was observed in each growth stages. CO_2 flux was lower at germination stage (June 2010) and the total CO_2 absorbance at this stage was 63.1 gCO_2m^{-2}. CO_2 flux reached its maximum at stalk elongation stage (September 2010-January 2011) and total CO_2 absorbance at this stage was 2,448.3 gCO_2m^{-2}. Totally, CO_2 absorbance for the entire period of experiment was 4,300.4 gCO_2m^{-2}. Carbon use efficiency of the 1st ratoon cane was 2.13 tyield/tCO_2. From the results, it was concluded that the 1st ratoon sugarcane ecosystem was a CO_2 source during night hours and a CO_2 sink during the day time. Finally, for the entire growing season the 1st ratoon cane system is the sink of CO_2.**

Index Terms—**Carbon use efficiency, eddy covariance technique, first ratoon cane.**

I. Introduction

Sugarcane is an important economic crop in Thailand and the world not only for sugar production but increasingly also for a bioenergy crop due to its phenomenal dry matter production capacity [1]. Global sugarcane production now is estimated at 1,250 million tons a year while the total production of sugarcane in Thailand is about 106 million tons per year. Total planting area of sugarcane in Thailand is 1.42 million ha [2]. Carbon dioxide (CO_2) exchange between terrestrial ecosystem and the atmosphere one of the key process that affects atmospheric CO_2 concentration. In order to assess the role of the terrestrial ecosystem in the global CO_2 budget at present, and to predict its changes in the future under global warming, long-term observation of CO_2 exchange has been done in various ecosystems in the world [3], [4]. These observation sites are mostly located in forest ecosystems because these are believed to the be most influential terrestrial ecosystem in the global CO_2 budget. However, non-forest ecosystem, such as grasslands, wetland or agricultural field also cover some part of the land area and contribute to regional and global CO_2 budgets [5]. Gas fluxes can be measured using many methods and Eddy Covariance Technique (EC) is the new method which does not interfere with process of gas exchange between the surface source and the atmosphere [6]. This technique has been used to measure CO_2 flux, and many studies have been published [7]. However, most of gas exchange studies involved short-term measurements. In this paper, we present seasonal variation of CO_2 flux at a customarily cultivated single cropping sugarcane crop base on the results of a single season-long measurement of CO_2 flux using the EC technique.

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II. Material and Methods

A. Site Description and Period of Measurement

This site was conducted at the first ratoon cane which is locates at Cane and Sugar Industry Promotion Center, Kanchanaburi province, in Western Thailand. The site is located at latitude 14.03°N and longitude 99.68°E with an elevation of 22.37 m above mean sea level. The soil of the sugarcane field is sandy loam. A CO_2 flux measurement and meteorological tower was 6.0 m high and was erected in the center of plot area. The sugarcane fields around the tower were managed as single sugarcane-cropping fields following by a common management in this area. In this study, the data of the 1st ratoon cane growing season (9 June 2010-31 April 2011) were analyzed.

B. Meteorological Data Measurement

The meteorological parameter consisted of solar radiation (Rs), net radiation (Rn), total amount of rain, wind speed and wind direction, air temperature and relative humidity. All of the meteorological instruments were installed on the tower at a height of 6.0 m. The meteorological data were collected and averaged every 30 minutes and stored in data logger CR1000 (Campbell Scientific, Inc.).

C. Plant Growth

Plant-cane was planted in 30 June 2009 and the first ratoon cane started from 9 June 2010. Growth characteristics consisted of plant height, stem diameter, fresh and dry weight, leaf area (LA) and leaf area index (LAI). The samples were taken from 5 plots around the tower at monthly intervals commencing from 60 days after plant-cane was harvested

until the next harvest. Each samples consisted of the above-ground portions of all shoots, the shoots were separated into stem, leaf blade and leaf sheath. When the amount of sample was in excess, a portion of representative subsample was used for dry weight determination, extrapolated for a whole sample, which was designated as the total dry matter. All samples were oven-dried at 80°C until a constant weight was reached. Sugarcane growing stage separated by four different growth stage, comprising germination and emergence, tillering and canopy establishment, grand growth, and maturation which are 1, 2, 7 and 2 months in length, respectively [8].

D. Eddy Covariance Flux Measurement

CO_2 flux was measured by the Eddy Covariance technique. Three components of wind velocity and temperature fluctuation were measured with a sonic anemometer (CSAT-3; LI-COR, Inc., Lincoln, NE, USA). The density of CO_2 was measured with an open-path infrared gas analyzer (IRGA) (LI-7500; LI-COR, Inc., Lincoln, NE, USA). The sensor heads of the sonic anemometer and IRGA were mounted the tower at a height of 2.0 m above the plant canopy. The data from the sonic anemometer and IRGA were sampled at 20 Hz using a 16-bit digital data recorder and stored in data logger CR3000. Half-hourly flux density of the CO_2 was calculated from the covariance between the vertical wind velocity and the respective quantities. All data were downloaded to computer every week and the quality of data were checked against the standard meteorology [9]. The CO_2 flux data were shown in plus (+) and minus (-), the meaning of plus is CO_2 was released from ecosystem by plant and soil respirations to atmosphere, and minus indicated CO_2 was absorbed into crop community through photosynthesis.

E. Carbon Use Efficiency (CUE)

Carbon use efficiency (CUE) was the ratio of net primary production (NPP) to gross primary production (GPP), describes the capacity of plants to transfer carbon from the atmosphere to biomass [10]. CUE is equivalent to CUE = NPP/GPP [11], [12].

III. Results

A. Meteorological Data

Meteorological condition in the first ratoon cane during 9 June 2010-30 April 2011 was shown in Fig. 1. Daily average solar radiation (Rs) variation ranged from 3.29-27.56 $MJm^{-2}d^{-1}$, lower levels of solar radiation in March 2011. Net radiation (Rn) was increased after the sunrise and reached its maximum at noon. The daily average of Rn variation ranged from 0.63-22.55 $MJm^{-2}d^{-1}$. The trend of average air temperature (Ta) and average relative humidity (RH) were shown in Fig. 2. The time series of average air temperature (Ta) fluctuation was between 17.9-31.1°C, its minimum was 17.9°C in March 2011 and its maximum was 31.1°C in April 2011. The average relative humidity (RH) was 71% and its minimum was 53%. Total amount of rain fall during the study period was 345 mm and its maximum was 61.1 mm per day which occurred in 29 June 2010 (Fig. 3).

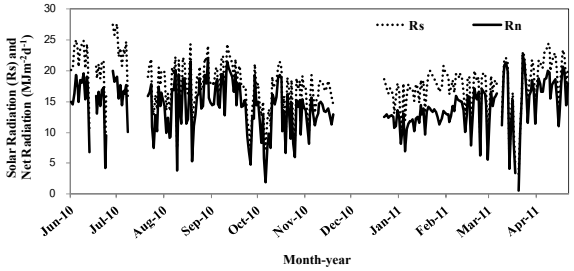

Fig. 1. Time series of solar radiation (Rs) and net radiation (Rn) at the experimental site from 9 June 2010-30 April 2011.

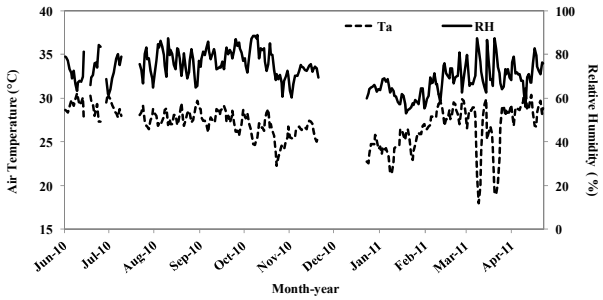

Fig. 2. Time series of average air temperature (Ta) and average relative humidity (RH) at the experimental site from 9 June 2010-30 April 2011.

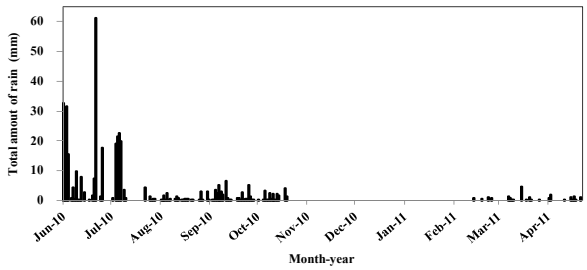

Fig. 3. Total amount of rain at the experimental site during 9 from 2010-30 April 2011.

B. Plant Growth Parameter

Plant height and diameter increased gradually from the beginning of measurement and reached the saturated point at age 7 month. Plant height was reached a maximum of 268.7 cm at maturity stage. The LAI showed a gradual increase from the tillering stage and reached a maximum at stalk elongation stage (Fig. 4)

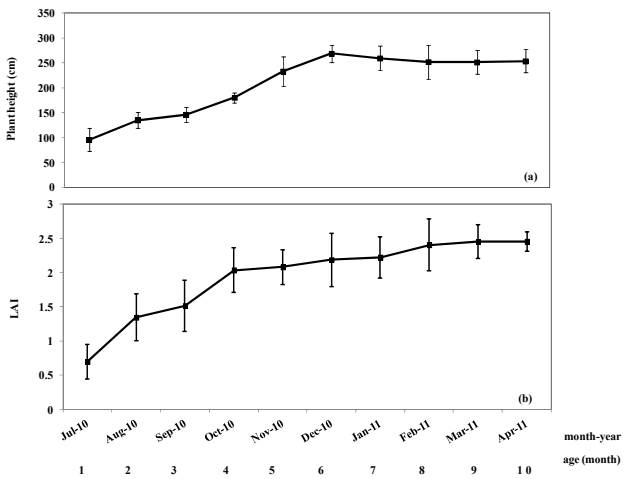

Fig. 4. The plant height (cm) and leaf area index (LAI) of the first ratoon cane.

C. Daily Trend of CO_2 Flux

All the data set of the first ratoon cane were analyzed for the daily trend of CO_2 flux. The daily trend of CO_2 flux was presented in Fig. 5. Throughout the measurement period, the daily values ranged from -0.5 $mgCO_2m^{-2}s^{-1}$ to 0.13 $mgCO_2m^{-2}s^{-1}$. It can be inferred that the fluxes of CO_2 were always positive during night hours with an average night time value of 0.11 $mgCO_2m^{-2}s^{-1}$, whereas during the day time the flux was negative with a corresponding value of -0.17 $mgCO_2m^{-2}s^{-1}$. Total CO_2 released of 4.8 gCO_2m^{-2} and total CO_2 absorbed of 12.4 gCO_2m^{-2} were observed.

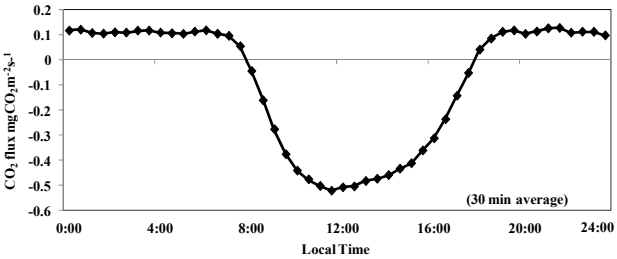

Fig. 5. Daily trend of CO_2 flux of the first ratoon cane from 9 June 2010-30 April 2011.

D. Daily Trend of CO_2 Flux in Each Growing Stage

In each growing stage daily trend of CO_2 flux was similar, the daily trend of CO_2 flux were increased in early morning and reached it maximum at noon then it was decreased in the afternoon. On the other hand, this variance of CO_2 flux in each growing stage. In germination, tillering, grand growth and maturation the variation range between -0.16 to 0.26, -0.54 to 0.20, -0.61 to 0.12 and -0.42 to 0.13 $mgCO_2m^{-2}s^{-1}$, respectively (Fig. 6.)

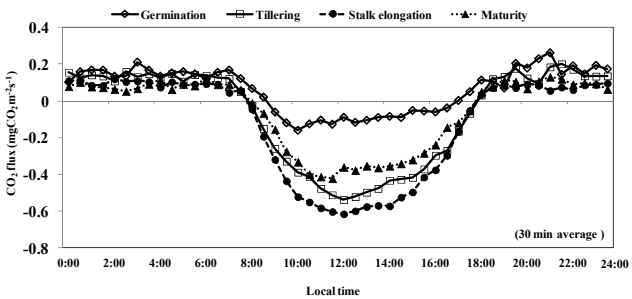

Fig. 6. Daily trend of CO_2 flux in each growing stage of the first ratoon cane from 9 June 2010-30 April 2011.

E. Seasonal Trend of CO_2 Flux

Seasonal variation of CO_2 flux was shown on Fig. 7. The daily values ranged between 0.05 to 31.1 $gCO_2m^{-2}d^{-1}$. The CO_2 flux summation at germination stage (0-1 month), tillering stage (2-3 month), stalk elongation stage (4-8 month) and maturity stage (9-11 month) were 63.1, 838.2, 2,448.3 and 950.8 gCO_2m^{-2}, respectively. At stalk elongation stage the CO_2 flux reached maximum cause of high LAI and this period which are 5 months in length. Totally, CO_2 absorbance of 4,300.4 gCO_2m^{-2} of the 1st ratoon cane was recorded.

F. Carbon Use Efficiency of the 1st Ratoon Cane

Throughout the 1st ratoon cane growing season, sugarcane biomass was 83.75 ton/hectare. And the 1st ratoon cane field can be absorbed CO_2 4,300.4 gCO_2m^{-2}. Carbon use efficiency on the 1st ratoon cane was 2.13 tCO_2/tyield.

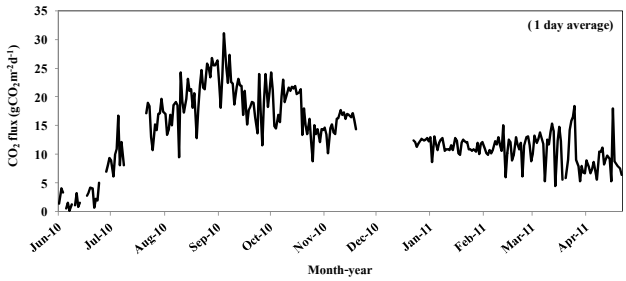

Fig. 7. Seasonal trend of CO_2 flux of the first ratoon cane from 9 June 2010-30 April 2011.

IV. Discussion

During the day time plant photosynthesis leads to uptake of CO_2 from both the atmosphere and from respired CO_2 emitted by the soil. Respiration at night leads to an efflux of CO_2 to the atmosphere [13]. Reference [14] found that the carbon storage content of sugarcane plantation in one crop yield consists of the carbon storage in sugarcanes and the organic carbon deposits in the soil. This carbon storage content was increases when the sugarcane grows. The results were similar to the reported in paddy fields as in [15] found that CO_2 flux was lower in stage I because of small LAI, then, gradually in increased and reached its maximum in the later stage. Moreover, CO_2 flux decreased in stage IV, probably due to the leaf senescence. Net exchange of CO_2 between crop community and the atmosphere is controlled by several biological and physical processes. It is well accepted that CO_2 storage with in the forest canopy has to be taken into account wherever we discuss the net CO_2 exchange between the ecosystem and the atmosphere [16].

V. Conclusion

During the night time the first ratoon cane was a CO_2 source originating from plant and soil respiration and during the day time became a CO_2 sink during the day time as plant photosynthesis advanced. However, for 24 hr period, it was a CO_2 sink. Different of CO_2 flux was observed in each growing stage. And CO_2 absorption in germination stage, tillering stage, stalk elongation stage and maturity stage was 63.1, 838.2, 2,448.3 and 950.8 gCO_2m^{-2}, respectively. Totally CO_2 absorbance which is 4,300.4 gCO_2m^{-2} of the first ratoon cane was found. Carbon use efficiency of the 1st ratoon cane was 2.13 tyield/tCO_2. From this result it was concluded that the 1st ratoon sugarcane ecosystem is a sink of CO_2.

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