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Climate Change and CO_2 Management

PROCEEDINGS

International Conference on

"Climate Change and CO_2 Management: Mitigation, Separation and Utilization"

February 2nd - 3rd, 2012

Organized by

CENTRE FOR ENVIRONMENTAL STUDIES, ANNA UNIVERSITY, CHENNAI, INDIA

in association with

Centre with Potential for Excellence in Environmental Sciences, Centre for International Affairs,

&

Centre for Climate Change and Adaptation Research Anna University, Chennai, India

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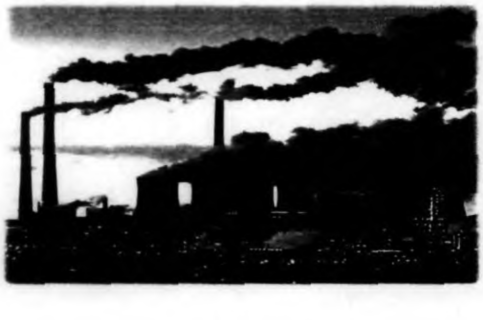

Proceedings of The International Conference on " Climate Change and CO2 Management : Mitigation, Separation and Utilization"
2-3, February, 2012 CES, Anna University, Chennai, India

Measurements of CO_2 and Water Flux in Natural Rubber Ecosystem

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ABSTRACT

Natural rubber plantations have the capacity to sequester significant quantities of CO_2 from the atmosphere into biomass and thus, they help to mitigate the rise in atmospheric CO_2 concentration to a certain level. There are several methods to study the CO_2 sequestration potential of a perennial plantation crop like natural rubber. Eddy covariance (EC) method is a state-of-the-art technology in which the fluxes of CO_2 and water vapour in any ecosystem can be measured in real time. In the present study, we describe ecosystem level net CO_2 sequestration and evapo-transpiration (ET) rates for a continuous two year period in a four-five year old natural rubber plantation. From the EC data, the net ecosystem exchanges (NEE) of CO_2 and water vapour were calculated. The net CO_2 exchange obtained from the system is the difference between photosynthetic assimilation by the canopy and the total respiratory efflux from the foliage, roots and soil. On an average, the NEE was 12g CO_2/m^2/day which is equivalent to 36 t CO_2/ha/year. The ET values calculated from the latent heat of vapourization (LE) indicated a 3-4 mm net evaporative water loss from the rubber plantation per day.

The current rate of build up of CO_2 in the atmosphere is about 2 ppm/year. The rate of CO_2 sequestration by rubber plantation ranges from 25-40 t CO_2/ha/year. Taking a modest average rate of 30 tCO_2/ha/year, the world's 10.4 million ha of natural rubber plantations help to offset the current rate of build-up of CO_2 in the atmosphere to the tune of 1.9%. This is a significant ecosystem service provided by the natural rubber plantation.

KEYWORDS: ***Atmospheric CO_2, Carbon sequestration, Eddy covariance, Rubber plantations.***

INTRODUCTION

Green house gases (GHGs) accumulating in earth's atmosphere from anthropogenic activities are warming the world's climate system. Climate change as a result of global warming can influence the growth and productivity of agricultural crops (Cynthia *et al.*, 2001). CO_2 is the most important global warming gas emitted by human activities (Solomon *et al.*, 2007). Sequestration activities can help prevent global climate change by enhancing carbon storage in trees and soils and by reducing emissions of GHGs (Suruchi and Singh, 2002). Carbon sequestration is the process through which agricultural and forestry practices remove carbon dioxide (CO_2) from the atmosphere by the process photosynthesis and stored in the biomass of plants. Roughly between 45 and 55 % of plant biomass is carbon (Malhi *et al.*, 2001). In the ecosystem point of view the stored biomass is as a result of net ecological exchange of carbon (NEE). Some of this stored carbon in plants transferred into soils when vegetation, litter and roots decay.

While annual agricultural crops also sequester large amounts of CO_2 from the atmosphere, almost the entire amount of carbon stored in the plant body is returned to the atmosphere at the end of the crop cycle. This is not so in forestry or perennial plantation crop. For example a plantation like natural rubber (*Hevea brasiliensis*) has an economic life cycle of 25- 30 years therefore the sequestered CO_2 will not come out to the atmosphere for this long. Other than sequestering CO_2 into its plant biomass natural rubber plantation helps to mitigate the atmospheric CO_2 concentration by supplying natural rubber which can be used in place of synthetic rubber that are produced from petroleum stocks. There are several methods to study the CO_2 sequestration potential of a perennial plantation crop like natural rubber. Biomass inventory method is the most easily available and commonly used method which gives an estimate of the total amount of carbon stored in the various components over a period of time (Jacob and Mathew, 2004; Jacob, 2005). In the present study a state- of- the-art method known as eddy covariance (EC) technique was used for CO_2 and water flux measurements in rubber plantation for a period of two years.

MATERIALS AND METHODS

The experimental site was situated at Central Experimental Station (CES) of Rubber Research Institute of India (RRII), Chethackal, Pathanamthitta District, Kerala. South India. The location is 9° 26'N and 76° 48'E. The observation site, an immature (four - five year old) plantation, with different *Hevea* clones, was spread over more than five hectare area with uniform growth. The average height of the trees was 10 m and girth was 35 cm at 150 cm above the bud union of the plant.

Carbon dioxide (Fc) and water vapour fluxes (LE) of the plantation were continuously measured by eddy covariance (EC) technique. The EC equipments were commissioned in a flux tower of 18 m height and the sensors were fixed on the tower at 4 m above the canopy. This method is more sophisticated micro-meteorological method in which the fluxes of CO_2 and water vapour and three-dimensional wind velocities are measured on real time basis (Baldocchi 2003). The EC system comprises of a three dimensional sonic anemometer (CSAT3, Campbell, USA) which is used together with an open path infra red gas analyzer (Li-7500, Li Cor, USA). Additionally the system is equipped with a net radiometer (NR-Lite, USA) and temperature and relative humidity (RH) sensors (HMP 45, Vaisala). The data collected were corrected by Edi Re software and processed into half-hourly values. The CO_2 flux (Fc) and the water vapour flux (LE) data were corrected for density effects (Webb *et al.*, 1980). Daily diurnal NEE and day and night flux rates were also calculated. The latent heat of vapourization (LE) was converted in to evapo transpiration (ET) on per day basis

The dry weight of above ground rubber tree biomass was calculated using the Shorrock's regression model:

$W = 0.002604\ G^{\wedge 2.7826}$ (Shorrocks *et al.*, 1965)
where, G is trunk girth (cm) at the height of 150 cm from bud union.

Generally the root biomass is 15-20% of shoot biomass in the case of natural rubber plants. The amount of carbon stored in the trees was analyzed by estimating annual biomass increment of trees.

RESULTS AND DISCUSSION

The CO_2 and water flux values were continuously measured for two- year- period (April 2009 to March 2011). The downloaded and corrected data table contains half hourly mean values of net radiation, air temperature, relative humidity (RH), fluxes of CO_2 (Fc), water (LE) and sensible heat (H). The daily pattern of CO_2 exchange showed positive and negative values (Fig. 1). Positive values measured during the night indicated net efflux of CO_2 from the ecosystem to the atmosphere, *i.e*, net ecosystem respiration (Reco). The flux values during daytime were mostly negative indicating net CO_2 assimilation by the ecosystem, i.e, net photosynthesis. The net ecosystem exchange of CO_2 (NEE) was determined as the arithmetic sum of the gross ecosystem exchange (GEE) and ecosystem respiration (Fig. 1). A negative sign in flux values indicated carbon sink. The net rate of canopy CO_2 assimilation during day time was always higher than the respiratory CO_2 efflux during night time. This observations clearly indicated that the net assimilation rate of canopy is higher than the net respiratory CO_2 efflux in natural rubber ecosystem.

NEE increases when the photosynthetically active radiation increases in the morning (Fig. 1). NEE decreases in late afternoon probably due to lesser light intensity and stomatal closure. The daily NEE by the rubber ecosystem ranged from 1-25g/m^2/day was recorded during the study period (Fig 2). Most of the days recorded CO_2 influx in to the plantation; however, a few days recorded net carbon efflux from the plantation to atmosphere and during these days there was rainfall and relatively less sunshine hours. The net efflux values in certain days included the possible high rate of total soil respiration (Rs) both by autotrophic (Ra) and heterotrophic (Rh) components of the soil in addition to the net CO_2 release from leaf respiration. Heavy rainy days witnessed a net efflux of CO_2 to atmosphere, most probably, due to a low rate of canopy photosynthesis and possible sudden spurt in release of locked up CO_2 from the soil. The average NEE during these two year period was 12g CO_2/m^2/day which is equivalent to 36 tons CO_2/ha/year. The net CO_2 assimilation (Aeco) and net respiratory CO_2 efflux (Reco) were worked out for the first year observation. While the mean Reco was 2.5g CO_2/m^2/day, the net assimilation rate (Aeco) recorded as 13.5g CO_2/m^2/day (Fig. 3). The rate of evapotranspiration (ET) also recoded for these periods in the immature rubber plantation. The mean ET was 3.5 mm/day during the study period. The water flux for a one year period is given in Fig. 4. The water flux data derived from EC system were almost similar to conventional lysimetric method in the traditional rubber growing areas of Kerala (Jessy *et al.*, 2002).

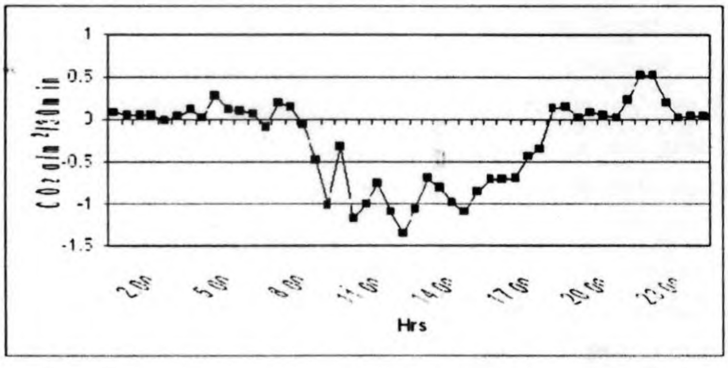

Fig 1. Typical diurnal CO_2 flux in an immature rubber plantation (5 years old). The negative and positive values indicate net assimilatory CO_2 during day time and net respiratory CO_2 release during night time, respectively.

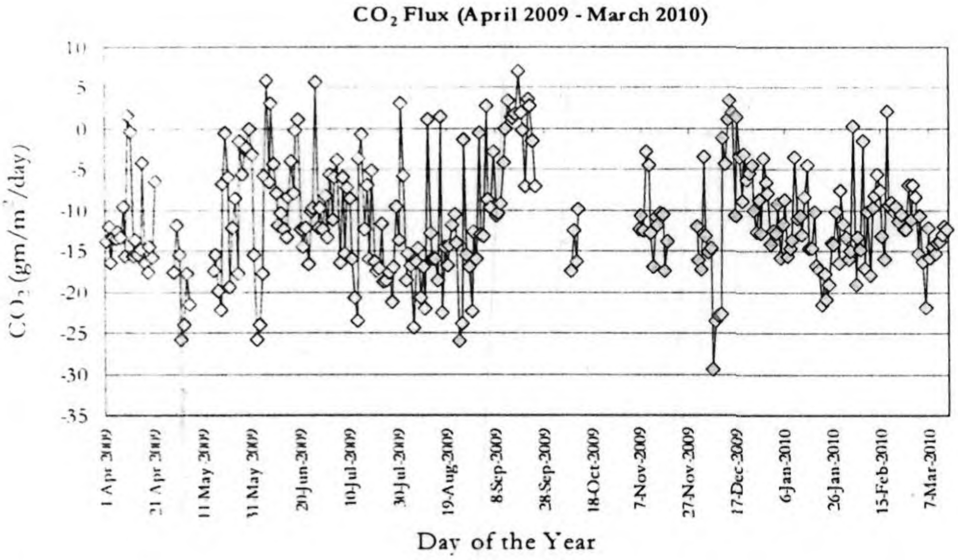

Fig. 2. The CO_2 flux (Fc) in four- five years old immature rubber plantation in central Kerala region of India for a continuous one year period. Gap filling was not carried out. The gaps in the data series indicated failure of the sensors during heavy thunder showers etc.

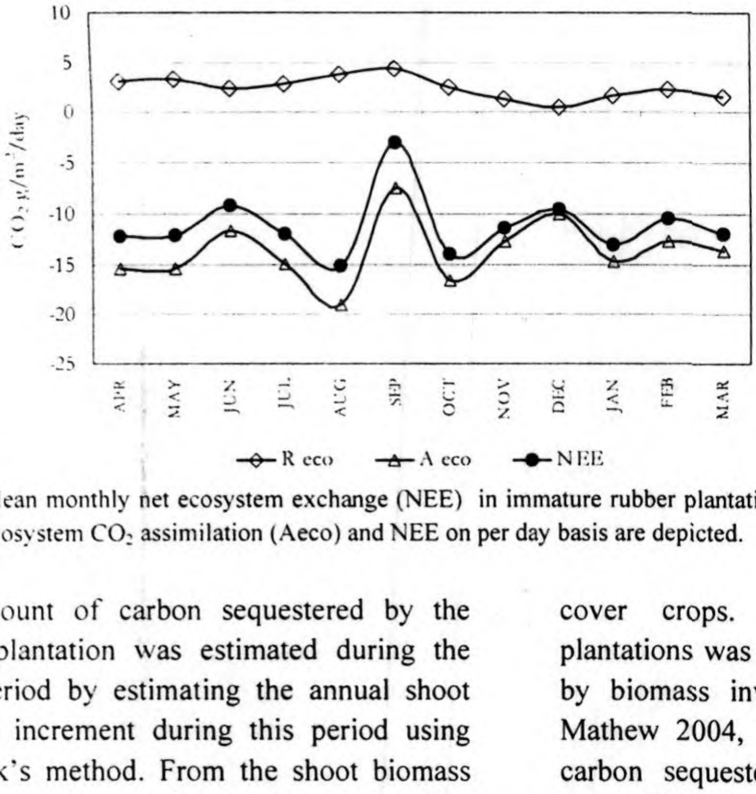

Fig. 3. Mean monthly net ecosystem exchange (NEE) in immature rubber plantation. The mean ecosystem respiration (Reco), ecosystem CO_2 assimilation (Aeco) and NEE on per day basis are depicted.

The amount of carbon sequestered by the rubber plantation was estimated during the same period by estimating the annual shoot biomass increment during this period using Shorrock's method. From the shoot biomass estimation, the amount of CO_2 sequestration was calculated as 17.5 t CO_2/ha/yr which does not include root biomass, soil respiration, litter decomposition and sequestration by weeds and cover crops. Carbon stock in rubber plantations was worked out by many workers by biomass inventory methods (Jacob and Mathew 2004, Wauters *et al.*, 2008). Total carbon sequestered by rubber plantations under Kerala (South India) conditions for a 21 year period was estimated to be 67 t C/acre and it was reported that the sequestration capacity of rubber plantation is much higher than most other terrestrial ecosystems (Jacob and Mathew, 2004). A 14 year old rubber stand has a carbon stock of 76 t C ha^{-1} in its above ground biomass whereas the contribution of the soil organic carbon pool was amounted to 135 t C ha^{-1} (Wauters et al. 2008).

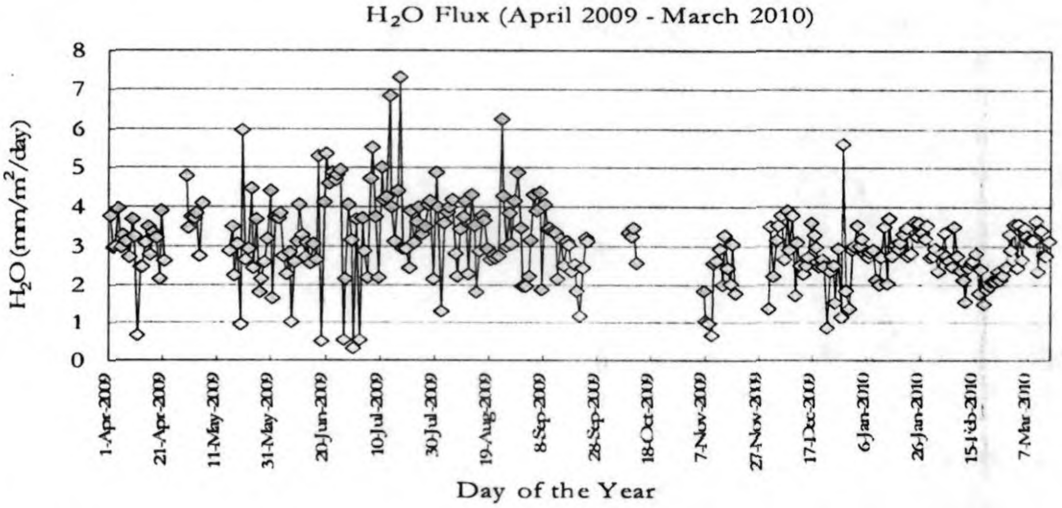

Fig. 4. The water flux (mm/m^2/day) in four- five years old immature rubber plantation in central Kerala region of India for a continuous one year period.

Our studies showed that natural rubber plants are good sink for atmospheric CO_2. Cultivation of rubber trees on non forested land could act as carbon sink by sequestering carbon in to biomass and organic carbon in soils. It is a good land use option to mitigate rising concentration of CO_2 in the atmosphere. The current rate of build up of CO_2 in the atmosphere is about 2 ppm/year. The rate of CO_2 sequestration by rubber plantation ranges from 25-40 t CO_2/ha/year. Taking a modest average rate of 30 t CO_2/ha/year, the world's 10.4 million ha of natural rubber plantations help to offset the current rate of build-up of CO_2 in the atmosphere to the tune of 1.9%. This is a significant ecosystem service provided by the natural rubber plantation.

ACKNOWLEDGEMENT

The authors thank Dr. Mallinath Priyadarshan, Deputy Director, Central Experimental Station, Chethackal and Dr. R. Krishnakumar, Joint Director, Crop Physiology Division, RRII for their help in commissioning tower and observations.

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