

# Chapter 31

## Soil Carbon Dioxide Efflux and Atmospheric Impact in a 10 Years *Dipterocarpus* Recovering Lowland Tropical Forest, Peninsular Malaysia

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**Abstract** Recovering logged-over forest ecosystem increases CO<sub>2</sub> efflux into the atmospheric carbon pool in response of environmental factors to change in soil temperature and moisture. These CO<sub>2</sub> outbursts can have a marked influence on the ecosystem carbon balance and thereby affect the atmospheric carbon pool. The study was conducted in a 10 years logged-over forest of Sungai Menyala forest, Port Dickson, Negeri Sembilan, Malaysia. The measurements of soil CO<sub>2</sub> effluxes were conducted using a continuous open flow chambers technique connected to a multi gas-handling unit and infrared CO<sub>2</sub>/H<sub>2</sub>O gas analyser. The aim of this study is to determine the percentage of CO<sub>2</sub> contributed into the atmosphere from a recovering 10 year logged-over lowland forest. One-way analysis of variance (ANOVA) was used to test the significance correlation between soil CO<sub>2</sub> efflux and environmental variables. Post-hoc comparisons were made using Tukey test ( $p < 0.05$ ), and multiple linear regressions were used to determine the impact of environmental factors on soil CO<sub>2</sub> efflux. Soil CO<sub>2</sub> efflux range from 345.6 to 600.4 mg/m<sup>-2</sup>/h<sup>-1</sup> with the highest efflux in the afternoon attributed to increase in soil temperature and moisture. Higher soil temperature and moisture recorded signify the influential factor. Furthermore, the predictor environmental variables;

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Soil Organic Carbon (SOC), Total Organic Carbon (TOC), Soil Moisture Content (SMC), Bulk Density, Below Ground Carbon Stock, Total Aboveground Carbon Biomass (TAGB), soil pH, Nitrogen to Carbon ratio account for the spatial and temporal variation in soil CO<sub>2</sub> efflux. These factors attributed to increase in CO<sub>2</sub> efflux into the atmosphere.

**Keywords** Soil CO<sub>2</sub> efflux · Carbon pool · Biomass · Forest ecosystem and carbon sink

## Highlights

- Age of trees and canopy density are key factors for carbon input.
- Soil properties and carbon stock are the determinants factors for soil CO<sub>2</sub> efflux.
- The tropical rainforest deforestation increases soil temperature and moisture.
- High rate of soil CO<sub>2</sub> efflux increases forest and atmospheric carbon pool.

## Introduction

Increase in the greenhouse gas from oceanic, terrestrial and atmosphere carbon pool has been considered as a major contributor to global warming as well as climatic change (Conant et al. 2011). However, recovering forest of the terrestrial ecosystems are consider among the deforested areas to emit high efflux of soil carbon dioxide (CO<sub>2</sub>) to the atmosphere (Brito et al. 2013). Soil CO<sub>2</sub> has been estimated to comprise of about 50–80 % of the terrestrial ecosystem respiration (Davidson et al. 2000a; Giardina and Ryan 2002), with a total of 60–80 Pg carbon annual (Raich and Potter 1995).

Recovering forest resulted from deforestation are found to have great implication on the atmospheric carbon pool, by contributing much percentage of CO<sub>2</sub> compared to undisturbed forest ecosystem (Ewel et al. 1981; Toland and Zak 1994). This action will resulted to unexpected change in physiological activity, microbial activity, litter fall input and root density, thereby increases efflux of soil CO<sub>2</sub> into the atmosphere as result of change in temperature and decay of fine roots (Hanson et al. 2000). In spite many researches on CO<sub>2</sub> efflux, little has been documented on the impact of recovering *Dipterocarpus* lowland tropical forest of peninsular Malaysia. This study will examine the rate and percentage of soil CO<sub>2</sub> efflux in the recovering 10 years forest and its contribution to the atmospheric carbon pool.

## Materials and Methods

### *Site Description*

Field experiment was conducted over a period of 6 months, January to June 2013, in the 10-year recovering logged-over *Dipterocarp* forest of Sungai Menyala, Port Dickson, Negeri Sembilan, Malaysia. The reserve forest is an extension forest for Seremban forest reserve. The study area is approximately 55 km from Kuala Lumpur. The reserve forest experiences equatorial climatic conditions with a temperature of 23.7 °C and relative humidity of 59–96 %, with an average of 83 %. Three experimental plot of 50 × 50 m, 70 × 70 m and 100 × 100 m with replicate were designed.

### *Soil CO<sub>2</sub> Efflux and Environmental Variables Measurement*

Soil CO<sub>2</sub> efflux was measured each day from 0800 to 1700 h for 6 month, using two continuous open flow chambers connected to a multi gas-handler, which provides a channel to regulate the flow of CO<sub>2</sub> from various chambers to a flow meter connected to a CO<sub>2</sub>/H<sub>2</sub>O gas analyser. Soil temperature, soil moisture and soil water potential were measured at a depth of 5 cm at intervals of 5 min concurrently with each soil CO<sub>2</sub> chambers.

Litter trap net was placed 1 m above the forest floor of ten each in a plot for the collection of leaves at 14 days interval to ascertain Carbon to Nitrogen ratio. Total aboveground biomass and leaves area index (LAI) were determined both measuring a total 630 trees in each plot. Soil samples were taken randomly at three sampling points of each plot from a depth of 0–100 cm. Standard method was used to analysed for SOC, SMC, bulk density and pH while Walkley–Black method was used to determine TOC (Sollins et al. 1999), and below ground carbon stock was based on Eleanor 2008 method. To establish the attribution of the environmental variables to soil CO<sub>2</sub> efflux, and recovering 10 years forest, a statistical correlation and multiple linear regression models was employed. Also principal component analysis (PCA) was used to reduce large dataset (Yongming et al. 2006).

## Results and Discussion

Based on the hourly and daily soil temperature and moisture changes, it was observed that soil CO<sub>2</sub> efflux significantly varies. Efflux ranged between 345.6 to 600.4 mg/m<sup>-2</sup>/h<sup>-1</sup> across the 10 years logged-over *Dipterocarp* forest from 0800 to 1700 h with the low efflux occurring in the morning hours of 0800 to 1100 h and an instantaneous high efflux rates at 1300–1500 h. Higher values were

recorded in the month of January to March and lower efflux was experienced between April to June. The corresponding values for soil temperature, moisture and water potential in 5 cm soil depth fluctuate across the months from 23 to 25 °C, 18–38 % and 96.6–97.6 %, respectively. Soil bulk density increased with depth with a corresponding high value of top 10 cm soil containing TOC and SOC of 1.9 % and 5.55 %, respectively. Soil moisture content occurred at 20.0 with a corrective factor 1.2. The soil pH of the study area was slightly acidic in nature (5.55). In addition, carbon and nitrogen input from litter fall contributed about 42.92 % and 1.16 %, respectively with soil total carbon in top 100 cm was 75.2 Mg C/m<sup>2</sup>.

The total amount of soil CO<sub>2</sub> contributed in the logged forest to the atmospheric carbon pool was calculated based on the flow rate and soil area sampled. The result indicated lower soil CO<sub>2</sub> efflux of 345.6 mg/m<sup>-2</sup>/h<sup>-1</sup> in the morning, with the highest peak of 600.4 mg/m<sup>-2</sup>/h<sup>-1</sup> in the afternoon and with an efflux declining in the evening. This coincided with the daily soil temperatures variation across the day. However, there were significant differences in total daily efflux between the early months and mid months of the year.

The multiple linear regression models indicated a strong correlation between soil CO<sub>2</sub> and environmental variables ( $r = 0.85$ ,  $p < 0.001$ ), explaining the impact of soil temperature and moisture on soil CO<sub>2</sub> efflux and the overall CO<sub>2</sub> efflux into the atmosphere due to deforestation. Results also indicated soil CO<sub>2</sub> efflux rate was in respond to the increase in TOC, SOC, soil moisture content and the acidic. Bulk density increases with depth, indicating the role of pore spaces played in water movement, capacity exchange ratio, electric conductivity and microbial activity. The carbon to nitrogen ratio was attributed to canopy stand density based on the age of the forest, serving as a nitrate for microbial activities (lignin and cellulose). This explains the variation in soil respiration of different forest age stand. Therefore, the environmental factors were found to have much significantly relationship with soil CO<sub>2</sub> efflux across the 10 year logged-over *Dipterocarp* lowland forest.

## Conclusion

The total amount of soil CO<sub>2</sub> efflux from the 10 years logged-over forest as was computed in the derived equation, showed that the recovering forest ecosystem displayed high rate of CO<sub>2</sub> efflux of 600.4 mg/m<sup>-2</sup>/h<sup>-1</sup>. This shows that the interaction among the environmental factor influences soil CO<sub>2</sub> efflux, therefore resulting to high percentage of soil CO<sub>2</sub> efflux from the 10 year logged-over *Dipterocarp* forest into the atmosphere. This situation is created as a result of deforestation as the forest is recovering, having less canopy stand density to capture CO<sub>2</sub> for photosynthesis and also to serve as a carbon sink. Therefore the

negative impact resulted from this scenario, is the increase in CO<sub>2</sub> efflux into the atmospheric carbon pool. This result will also help to determine the rate and the percentage of soil CO<sub>2</sub> efflux into the atmospheric carbon pool due to deforestation in Peninsular Malaysia.

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