Soil Trace Gas Flux in a Costa Rican Premontane Wet Forest

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1. Introduction

Tropical forests are the largest global source of net primary production[1] and contain up to 40% of global terrestrial biomass [2]. The single largest component of carbon loss to the atmosphere is soil respiration[3]. It is therefore important to quantify the variability in soil gas exchange flux in the tropics and to evaluate its relationship with environmental variables to improve our understanding of the global carbon budget .

This study examined soil gas flux for CO_2, CH_4, and CO. Tropical forests are the largest natural source of CO_2[4]. Environmental conditions that control soil respiration – including soil and air temperature, soil moisture, and photosynthetically active radiation (PAR) – vary spatially, seasonally, and diurnally. Methane exchange is harder to characterize, because moist tropical soils can act as both a source and a sink of CH_4[5]. Although soil is considered an important sink of atmospheric CO, comparatively less is known about soil CO consumption[6]. The objectives of this study were to:

(1) quantify soil gas flux (CO_2, CH_4, CO) in a transitional cloud forest using a chamber technique

(2) identify the variability in gas flux, and

(3) investigate the contribution of forest litter to total respiration

Soil gas flux rates were measured bi-weekly for 6-weeks at 3 sites of varying soil properties and elevations during the transition from dry to wet season in Costa Rica.

2. Study Site

Research was conducted in a premontane wet forest located on the eastern-facing slope of the Cordillera Central Mountain Range, in northeastern Costa Rica (10°22' N, 84°37' W). The area is believed to have been selectively harvested, but is currently reserved for research and educational purposes.

Soil texture is a sandy clay and is volcanic in origin, with an average pH of 4.8. Average annual rain fall in the area is 350 mm/month. During the sampling period, total rainfall was 507 mm/month, and average air temperature was 25°C.

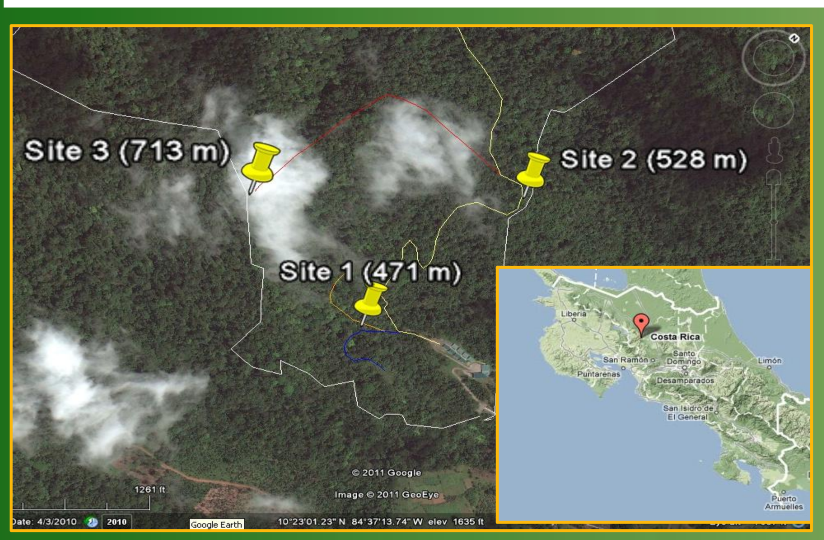

Figure 1. Map of sampling locations with elevation, and property trails/boundaries at the Soltis Center for Research and Education. All sites are sub-canopy

3. Methods

Soil gas flux rates were measured at 3 sub-canopy sites of varying elevation (Fig. 1). Sites were sampled twice-weekly over 6 weeks, during the transition from dry to wet season in Costa Rica.

Static gas chambers were used for flux measurements. The instruments and procedures for each method are outlined below:

- LI-COR 840A CO_2-H_2O Gas Analyzer (CO_2)
  - 6-8 chambers per site per day
  - Sample time of 5 minutes per chamber
  - CO_2 ppm recorded with HOBO data logger (10 s intervals)
  - Leaf litter vs. no leaf litter chambers (components of flux)
  - Diurnal measurements taken every 6 hours for 3-day period to examine diurnal cycle
- SRI 8610 Gas Chromatograph (CO_2, CH_4, and CO)
  - 10 mL syringes filled at 0, 1, 7, 14, 21, and 28 minutes after chambers closed[5]
  - 4 chambers per site per day
  - To test CO uptake, chambers injected with 2 syringes of car exhaust, and sampled in the subsequent 75-minute period

4. Results

- Observed CO_2 flux was slightly higher than literature values for similar tropical regions
- Averaged soil respiration values from different analysis methods (LICOR 840A CO_2-H_2O analyzer and SRI 8610 Gas Chromatograph) were within error of one another (Table 1)
- Methane was taken up by soil rather than emitted during the wet season, indicating the study site is a net CH_4 sink (Table 1)
- Carbon monoxide flux was higher than reported literature values

Table 1. Summary of averaged trace gas fluxes for each site, and for all sites combined, by sample method (LICOR 840A CO_2-H_2O analyzer and Gas Chromatograph). All flux measurements reported in g/m²/min. Includes averaged volumetric water content (VWC)

	Site 1	Site 2	Site 3	Average
CO_2 Flux (LICOR)	12.1±8.9E-3	20.5±6.8E-3	18.1±4.5E-3	16.8±7.8E-3
CO_2 Flux (GC)	9.92±9.8E-3	2.07±1.3E-2	1.95±0.95E-2	1.64±1.2E-2
CH_4 Flux	-5.64±3.2E-6	-10.7±8.0E-6	-6.44±4.6E-6	-7.89±6.2E-6
VWC(%)	30.1±5.4	22.0±3.2	28.6±3.0	27.0±5.4

4.1 Carbon Dioxide

- The average soil respiration rate for all sites (16.8±8E-3 g/m²/min) was within error of average respiration rates from three similar studies in the tropics (14.9±6E-3 g/m²/min) [3,7,8]

Carbon Dioxide Flux and Soil Moisture:

- Soil respiration is expected to be low under dry conditions, reach a maximum at some optimal moisture level, and decrease as high moisture prevents gas diffusion and anaerobic conditions depress microbial activity[9]
- Here, soil respiration rates were negatively correlated with soil moisture (Fig. 2), in agreement with previous findings [3,7,10]
- The observed correlation was most likely due to a decrease in soil gas diffusivity, causing inadequate oxygen supply to microorganisms, reducing microbial activity [11, 12,13]

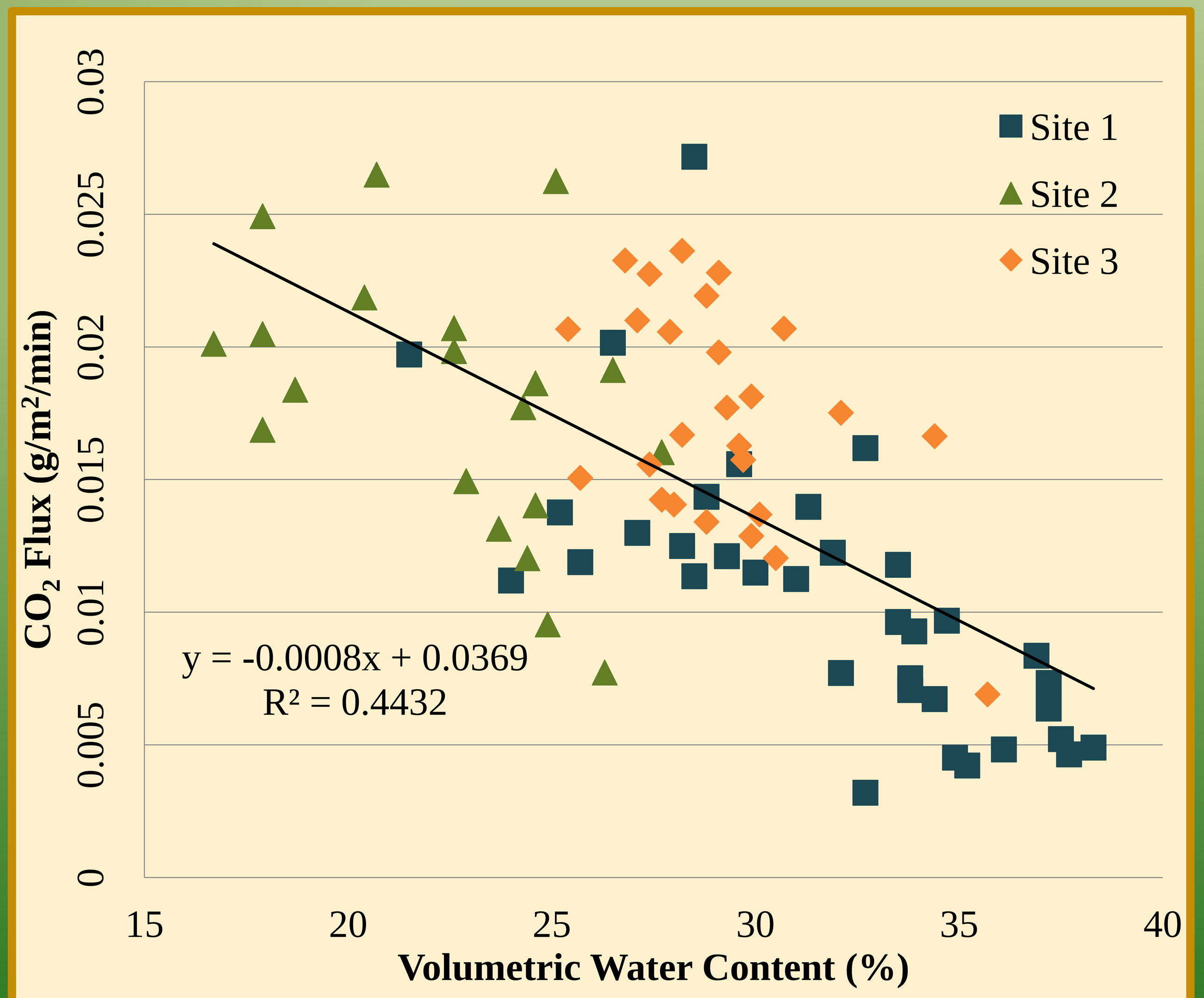

Figure 2. Negative relationship between soil moisture (VWC) and carbon dioxide flux (R^2=0.44) for all sites. Each point represents one static gas chamber analyzed with the LICOR 840A CO_2-H_2O analyzer. All flux measurements shown were collected in the morning, between 9 and 11 AM. Linear trendline represents relationship for all points.

Diurnal Changes in Soil Respiration:

- Soil respiration peaked during the 4-5 pm sampling period (Fig. 3) when soil reached its highest temperature, soil was moist from afternoon rains, and root respiration reached maximum potential (based on PAR)
- The second highest soil respiration period, 7-10 pm, occurred when soil was still moist and warm from the day, and reacting to previous, daytime photosynthesis
- While spatial variability is controlled by soil moisture (Fig. 2), diurnal fluctuations in soil respiration (Fig. 3) are the result of changes in soil temperature, root respiration, and soil moisture

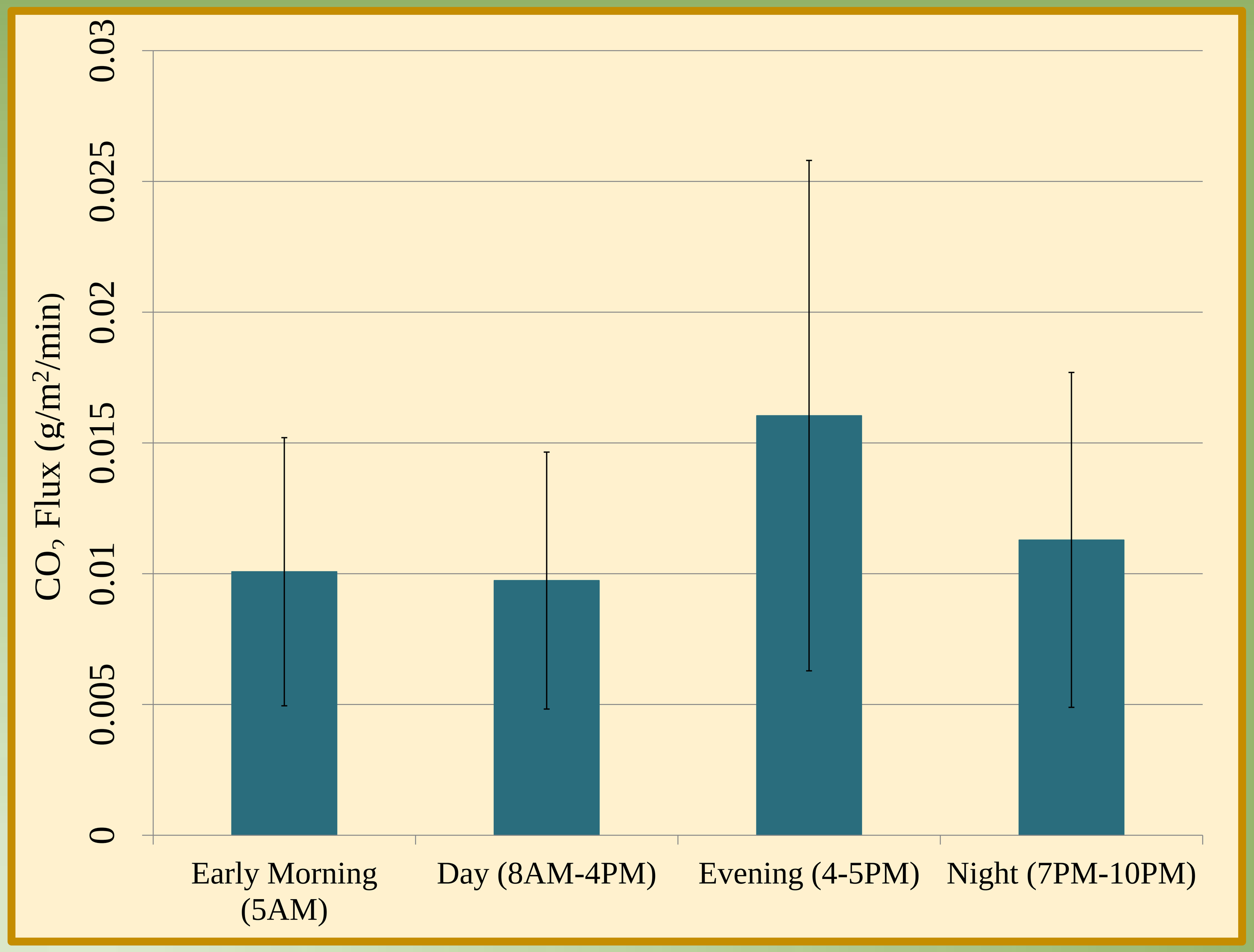

Figure 3. Diurnal fluctuations in carbon dioxide flux at Site 1 with error (standard deviation). Each flux value represents averaged soil respiration values for VWC values between 22.8 and 33.8% collected during a 3-day collection period. Soil respiration is highest in the evening, followed by night, early morning, and day

Leaf Litter Experiments:

- One study estimated that litter accounted for 37% of total soil respiration in a similar forest[14]
- However, averaging several litter vs. no-litter static chambers measurements from each site, there was no significant difference between soil respiration before and after litter was removed (Fig. 4)
- The lack of relationship may be explained by soil disturbance of roots and microorganisms when litter was removed, inflating flux values

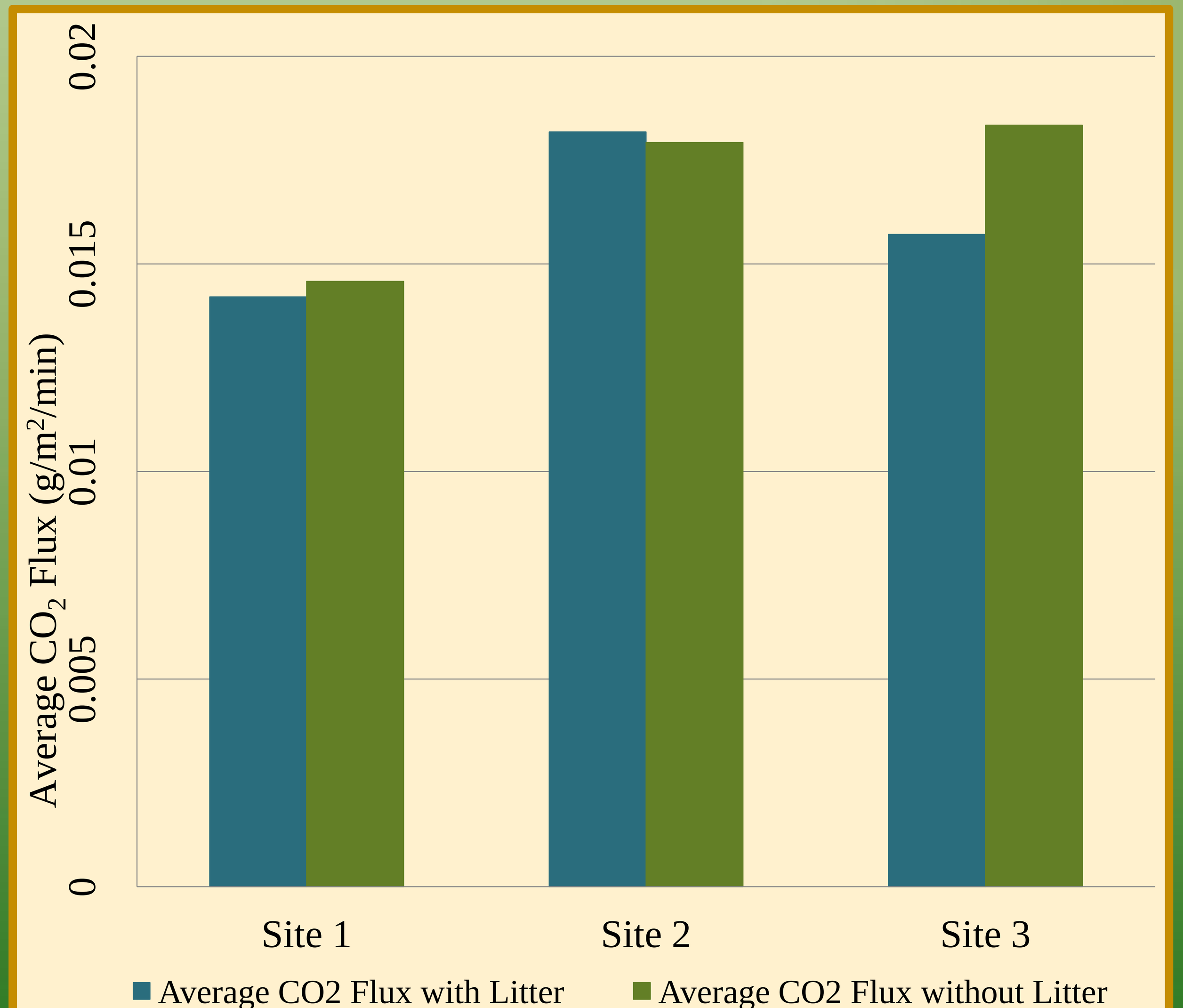

Figure 4. Average soil respiration, by site, for static chambers with forest litter was removed. Based upon results, it is not possible to identify the component of soil respiration derived from forest litter.

4.2 Methane and Carbon Monoxide

Methane

- The average methane uptake for all sites was -7.89±6.21×10^{-6} g/m²/min
- Forest soil was a net sink for methane, indicating that soils were sufficiently well-drained
- Observed flux was higher than that found in similar study[5]

Carbon Monoxide

- Observed deposition velocity at Site 2 was -1.9E-2 cm/s
- Uptake rate was extremely high compared to values for other tropical forests[6]
  - this is explained by the very high concentrations of CO introduced in order to achieve detectable concentrations

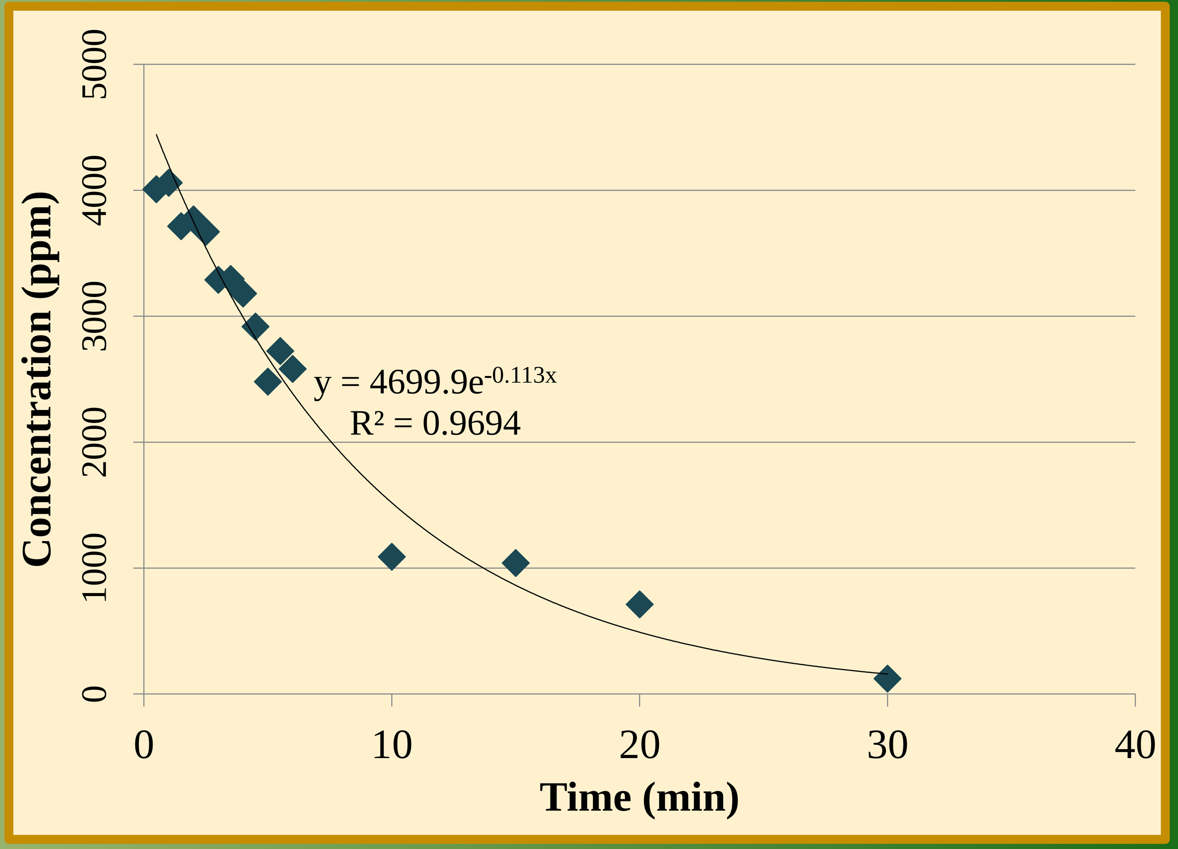

Figure 5. The carbon monoxide decline in the chamber after two exhaust injections at Site 2. Samples were taken every thirty seconds for the first six minutes, then at five or ten minute intervals for the remainder of the sampling period.

5. Summary

- Carbon dioxide flux was slightly higher than previously reported values in similar tropical environments
- CO_2 efflux was inhibited by higher soil moisture
- Over a 24-hr period, soil respiration was highest in the evening; a combination of high soil temperature, moisture, and root respiration
- Forest litter did not significantly contribute to total soil respiration
- On average, soils in the study area take up methane
- Variability for all gas flux measurements was highly

6. Acknowledgements

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