Soil CO2 Flux, Moisture, Temperature, and Litterfall, La Selva, Costa Rica, 2003-2010

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Documentation Revision Date: 2017-03-15

Data Set Version: V1

Summary

This data set provides measurements of soil carbon dioxide (CO2) emission rates, soil moisture, relative humidity (RH), temperature, and litterfall from six types of tree plantations at the La Selva Biological Station, Costa Rica. Soil CO2 flux and related measurements were made 1) hourly during 2-day diel field campaigns and 2) as single daytime measurements during multiple survey campaigns, over the period 2004-2010. All measurements were made at the same sites to compare hourly, monthly, and inter-annual variations. Most of the emissions data represent a single soil CO2 flux measurement, with three to five measurements per plot. Litterfall was collected monthly from 2003-2009 and was sorted into fractions prior to drying.

The experimental design included four randomized blocks composed of twelve 50-m x 50-m plots, each of which originally contained a single tree species planted at 3-m x 3-m spacing. Four replicate plots of six plantation types, a total 24 plots, were included in this study.

There are three data files in comma-separated format (.csv) with this data set.

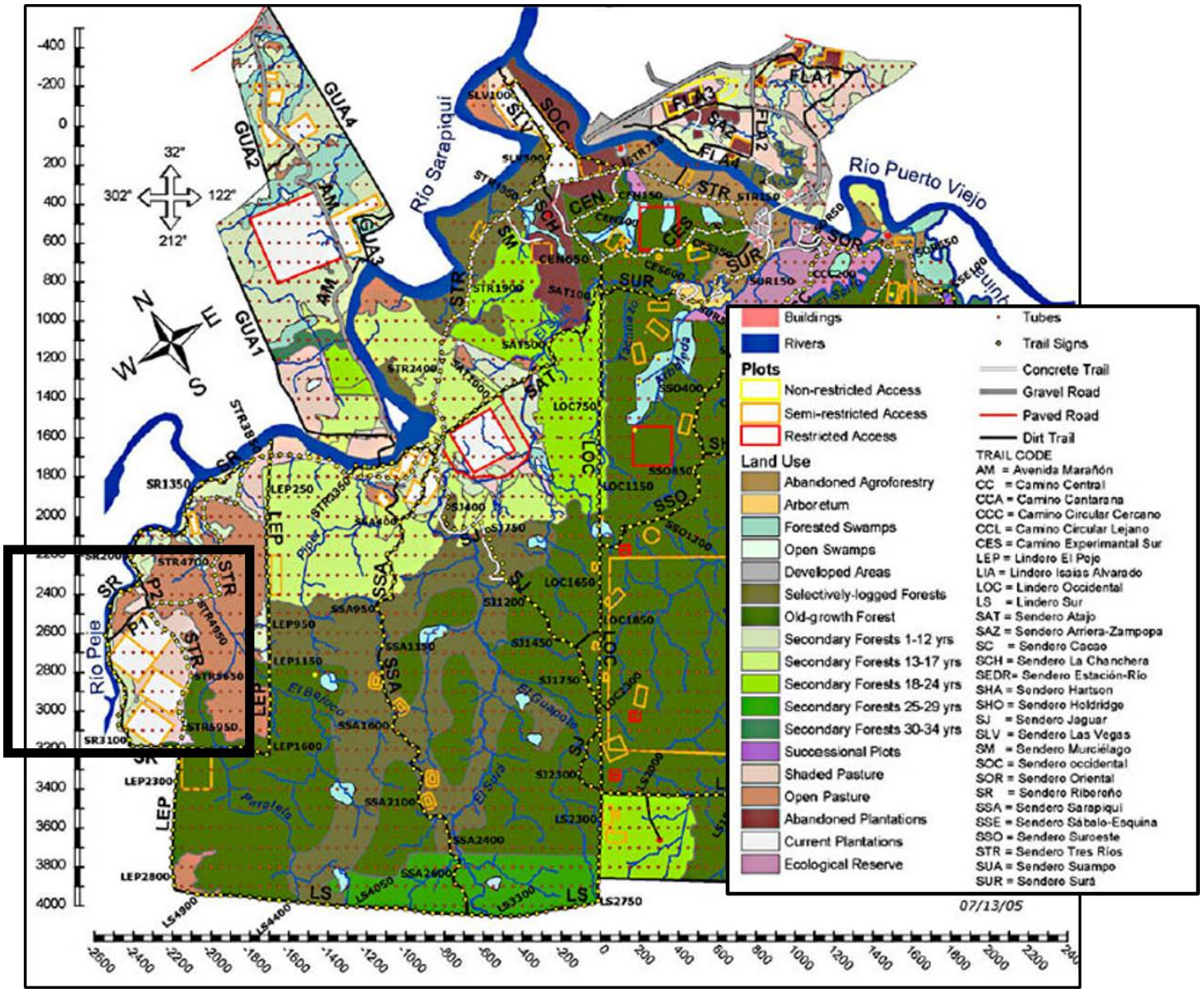

Figure 1. The LaSelva Biological Preserve, Costa Rica. The study site, with four blocks, is located on the left side of the map inside the black rectangle.

Citation

Raich, J.W., and O.J. Valverde-Barrantes. 2017. Soil CO2 Flux, Moisture, Temperature, and Litterfall, La Selva, Costa Rica, 2003-2010. ORNL DAAC, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1373

Table of Contents

1. Data Set Overview

This data set provides measurements of soil carbon dioxide (CO2) emission rates, soil moisture, relative humidity (RH), temperature, and litterfall from six types of tree plantations at the La Selva Biological Station, Costa Rica. Soil CO2 flux and related measurements were made 1) hourly during 2-day diel field campaigns and 2) as single daytime measurements during multiple survey campaigns, over the period 2004-2010. All measurements were made at the same sites to compare hourly, monthly, and inter-annual variations. Most of the emissions data represent a single soil CO2 flux measurement, with

three to five measurements per plot. Litterfall was collected monthly from 2003-2009 and was sorted into fractions prior to drying.

Field studies for this research were conducted to test the influence of tree species identity on soil properties after reforestation. The experimental design included four randomized blocks composed of twelve 50-m x 50-m plots, each of which originally contained a single tree species planted at 3-m x 3-m spacing (Fisher, 1995). These species included plantations of *Pinus patula* subsp. *tecunumanii* (Eguiluz & J. P. Perry) Styles; *Hieronyma alchorneoides* Allemao; *Pentaclethra macroloba* (Willd.) Kuntze; *Virola koschnyi* Warb.; *Vochysia ferruginea* Mart.; and *Vochysia guatemalensis* Donn. Sm. *Pentachlethra* is a Mimosoid legume with occasionally nodulated roots; *Pinus patula* was the only conifer and the only non-native species included. Litterfall measurements were made from October 2003 to December 2009 and were used to test for temporal offsets between leaf production and soil respiration.

Related Publications:

Fisher, R.F. Amelioration of degraded rain forest soils by plantations of native trees. 1995. Soil Science Society of America Journal 59: 544-549.

Raich, J.W. Temporal variability of soils respiration in experimental tree plantations in Lowland Costa Rica. 2017. Forests 8,40. http://doi.org/10.3390/f8020040

Raich, J.W., A.E. Russell and R. Bedoya-Arrieta. Lignin and enhanced litter turnover in tree plantations of lowland Costa Rica. 2007. Forest Ecol. Manage., 239: 128-135. http://doi.org/10.1016/j.foreco.2006.11.016

Russell, A.E., J.W. Raich, R. Bedoya, O. Valverde-Barrantes and E. González. Impacts of individual tree species on carbon dynamics in a moist tropical forest environment. 2010. Ecological Applications 20(4): 1087–1100. http://doi.org/10.1890/09-0635.1

Valverde-Barrantes, O.J. Relationships among litterfall, fine-root growth and soil respiration for five tropical tree species. 2007. Canadian Journal of Forest Research 37:1954-1965. http://doi.org/10.1139/X07-057

Acknowledgements:

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2. Data Characteristics

Spatial Coverage: The study area was located approximately 3.3 km from the Biological Station headquarters at LaSelva, Costa Rica

Spatial resolution: The study plots were 50-m x 50-m

Temporal Resolution: Hourly and monthly

Temporal Coverage: 2003-10-01 to 2010-02-25

Site boundaries: (All latitude and longitude given in decimal degrees)

Site (Region)	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
La Selva, Costa Rica	-84.05	-84.038	10.435	10.425

Data file information

There are three data files in comma-separated format (.csv) with this data set. In each file missing data is denoted as -9999.

Table 1. File names and descriptions.

File name	Description
LaSelva_DIEL_soil_CO2_flux_2004_2010.csv	Soil CO2 flux measurements, soil temperature and moisture, and tree species on the sample plots during 2-day diel measurement campaigns.
LaSelva_survey_soil_CO2_flux_2004_2010.csv	Soil CO2 daytime emissions measurements from the sample plots
	Litterfall measurements made from October 2003 to December 2009.

LaSelva_monthly_litter_2003_2009.csv	Litterfall is provided by four fractions: branches and bark; overstory leaves; other leaves; and miscellaneous materials. Oven-dry weights on a per-meter-squared per-day basis are provided, with carbon and nitrogen contents (%) where available.

Table 2. Variables in the data file **LaSelva_DIEL_soil_CO2_flux_2004_2010.csv.** All data in this file were collected as part of a study of diel fluxes from 2004-11-11 to 2010-02-07.

Column number	Variable	Units/format	Description
1	LICOR_filename		The file name from the LICOR 8100 logger used to collect data during a single measurement period at one site (see column **observation_num**)
2	Date	YYYYMMDD	Date of the start of the measurement
3	Time	hh:mm	Time of day when measurement was collected
3	hour-decimal		Hour of day in decimal format. Theoretical range 0.00000 to 23.99999
4	hour-text		Hour of day in text format as categorical variable in statistical analyses. Noon = 11:30am-12:30pm.
5	Time_Zone	CST	Central Standard Time (UTC-6)
6	observation_num		The number of the sequential measurement taken over one diel measurement period in one plot
7	block		The experimental block designator
8	species		Alphabetic code for the planted tree species: HIAL is Hieronyma alchorneoides; PEMA is Pentaclethra macroloba; PIPA is Pinus patula subspecies tecunumanii; VIKO is Virola koschnyi; VOFE is Vochysia ferruginea and VOGU is Vochysia guatemalensis
9	quad		One quarter of a full plot that totaled 50m x 50m and was bisected along each major axis into quarters (quads) that allowed for stratified random location of sampling points
10	CO2a	PPMV	The calculated concentration of ambient atmospheric CO2 at the time of chamber closure as expressed on a dry-air basis
11	CO2_Flux_Exp	micromole CO2 m-2 sec-1	The soil-CO2 emission rate
12	Tair	degrees C	The ambient air temperature at the beginning of a flux measurement
13	z(Tsoil)	cm	The depth at which soil temperature was measured (5 or 10 cm only)
14	Tsoil	degrees C	Soil temperature at the time of flux measurement at depth = z(Tsoil)
15	RH	%	Relative humidity of the ambient air as measured inside the chamber. In a few cases the calculated RH was >100% and those data are not excluded
16	Soil_H2O	%	Soil water content in the surface approximately 12 cm of soil in units of cm of H2O per cm of soil depth expressed as a percentage

Table 3. Variables in the data file **LaSelva_survey_soil_CO2_flux_2004_2010.csv.** These data were collected as part of a cross-site survey of daytime soil CO2 fluxes from experimental plantations of different tree species. The file contains survey measurements across plots within individual days from 2004-09-29 to 2010-02-25.

Column number	Variable	Units/format	Description
1	Measure_Period	YYYYMMDD	Date on which a measurement period began. Each measurement period was one to three days in duration and includes one complete set of data including measurements from each of the four experimental blocks
3	Date	YYYYMMDD	Date of the measurement
4	Time	hh:mm	Time of day when measurement was collected

5	Year-decimal		Date in real-number format for plotting and statistical analysis
6	DOY		Day of year. Ordinal number of the day of the year where January 1 = 1 and December 31 = 365 or 366
7	Month		Alphabetic month as categorical variable for sorting and statistical analyses
8	Hour-decimal		Hour of day in decimal format. Theoretical range 0.00000 to 23.99999
9	Hour-text		Hour of day in 2-digit text format for sorting and statistical analyses
10	TimeZone	CST	Central Standard Time (UTC-6)
11	Observation_num		The number of the sequential measurement taken during a measurement period
12	Block		The experimental block designator
13	Species		Alphabetic code for the planted tree species: HIAL is Hieronyma alchorneoides; PEMA is Pentaclethra macroloba; PIPA is Pinus patula subspecies tecunumanii; VIKO is Virola koschnyi; VOFE is Vochysia ferruginea and VOGU is Vochysia guatemalensis
14	Quad		One quarter of a full plot that totaled 50m x 50m and was bisected along each major axis into quarters (quads) to facilitate stratified random location of sampling points
15	CO2a	PPMV	The ambient atmospheric CO2 concentration at the beginning of a measurement as expressed on a dry-air basis
16	CO2_flux_exp	micromole CO2 m-2 sec-1	The soil CO2 emission rate
17	Tair	degrees C	The ambient air temperature at the beginning of a flux measurement
18	z(Tsoil)	cm	The depth at which soil temperature was measured (5 or 10 cm only)
19	Tsoil	degrees C	Soil temperature at the time of flux measurement at depth = z(Tsoil)
20	RH	%	Relative humidity of the ambient air at the beginning of the measurement. In some cases the calculated RH was >100% and those data are not excluded
21	Soil_H2O	%	Soil water content in the surface approximately 12 cm of soil in units of cm of H2O per cm of soil depth expressed as a percentage

Table 4. Variables in the file **LaSelva_monthly_litter_2003_2009.csv.** This file provides litterfall measurements made from 2003-10-01 to 2009-12-18.

Column number	Column name	Units/format	Description
1	Treatment		The experimental treatment expressed as an alphabetic code for the planted tree species: HIAL is Hieronyma alchorneoides; PEMA is Pentaclethra macroloba; PIPA is Pinus patula subspecies tecunumanii; VIKO is Virola koschnyi; VOFE is Vochysia ferruginea and VOGU is Vochysia guatemalensis
2	Block		The experimental block from 1 to 4
3	StartDate	YYYYMMDD	The date on which an empty litter trap was set in the field to collect falling litter
4	EndDate	YYYYMMDD	The date on which a litter trap was emptied of accumulated litterfall
5	TimeZone	CST	Central Standard Time (UTC-6)
6	Days		Number of days over which litterfall collections were combined for a month

7	Total_Fine_LF	g m-2 day-1	Oven-dry mass of total fine litterfall based on sum masses of the four measured fractions
8	Overstory_Leaf_LF	g m-2 day-1	Overstory-leaf litterfall including leaves rachises and petioles of only the planted overstory trees
9	Other_Leaf_LF	g m-2day-1	Other leaf litterfall includes all leaf material from species other than the planted trees
10	Twig_LF	g m-2 day-1	Small branches and bark less than or equal to 1-cm in diameter; larger branches were discarded
11	Misc_Fractions_LF	g m-2 day-1	Miscellaneous fractions of litterfall including arthropods; feathers; frass; moss; etc.
12	Overstory_Leaf_N	%	The nitrogen content of overstory leaf litterfall
13	Overstory_Leaf_C	%	The carbon content of overstory leaf litterfall
14	Other_Leaf_C	%	The carbon content of the combined leaves of all non-planted species collected in the litterfall traps
15	Twig_N	%	The nitrogen content of twigs and pieces of bark collected in the litterfall traps
16	Twig_C	%	The carbon content of twigs and pieces of bark collected in the litterfall traps
17	Misc_N	%	The nitrogen content of all combined miscellaneous materials collected in the litterfall traps
18	Misc_C	%	The carbon content of all combined miscellaneous materials collected in the litterfall traps

3. Application and Derivation

Field studies for this research were conducted to test the influence of tree species identity on soil properties after reforestation. These species included plantations of *Pinus patula* subsp. *tecunumanii* (Eguiluz & J. P. Perry) Styles; *Hieronyma alchorneoides* Allemao; *Pentaclethra macroloba* (Willd.) Kuntze; *Virola koschnyi* Warb.; *Vochysia ferruginea* Mart.; and *Vochysia guatemalensis* Donn. Sm. *Pentachlethra* is a Mimosoid legume with occasionally nodulated roots; *Pinus patula* was the only conifer and the only non-native species included. Litterfall measurements were made from October 2003 to December 2009 and were used to test for temporal offsets between leaf production and soil respiration (from Raich, 2017).

4. Quality Assessment

The raw data (including each regression) was quality checked with respect to expected values and physical realities. The first observation of each diel measurement period was deleted because of obvious contamination by human respiration during equipment set-up.

Variability of soil-CO2 emissions among locations, dates, and times was very high.

5. Data Acquisition, Materials, and Methods

Site description

The research was undertaken at the La Selva Biological Station of the Organization for Tropical Studies, Inc., in the Caribbean lowlands of northeastern Costa Rica. Over 1997-2009 annual precipitation averaged 4,537 mm; the dry season generally extends from February to April. Mean air temperature was 25.1 degrees C. The native vegetation at this site is species-rich broad-leaved evergreen rainforest that has a high abundance of *Pentaclethra macroloba* (Willd.) Kuntze (Fabaceae, Mimosoideae) trees, and many subcanopy palms. The soils were Oxisols derived from volcanic parent materials (Raich, 2017).

Study plots

The study plots were established at six single tree species plantations located on hilly terrain with elevations of 44 to 89 m approximately 3.3 km from the Biological Station headquarters and weather station. The experimental design included four randomized blocks composed of twelve 50-m x 50-m plots, each of which originally contained a single tree species planted at 3-m x 3-m spacing. Each block was centered across a single hill and thus encompassed a range of slope and aspect positions. Four replicate plots of six plantation types, a total 24 plots, were included in this study. These included plantations of:

- *Pinus patula* subsp. *tecunumanii*
- *Hieronyma alchorneoides* Allemao;
- *Pentaclethra macroloba* (Willd.) Kuntze;
- *Virola koschnyi* Warb.;
- *Vochysia ferruginea* Mart.;
- *Vochysia guatemalensis* Donn. Sm.

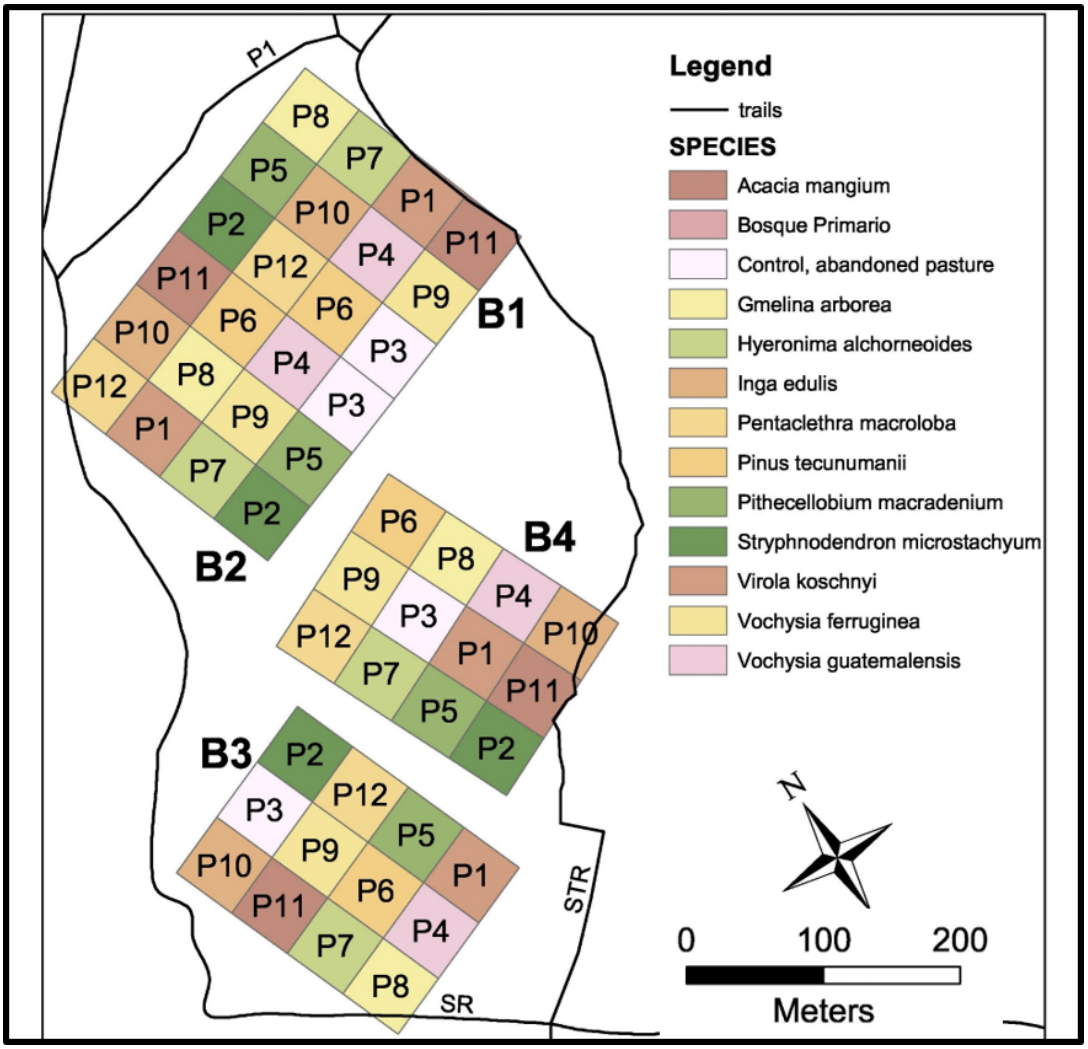

Figure 2. Four study plots of six single-tree species plantation types were used for this research. Note that blocks B1 and B2 are adjacent. Plot identifiers and species are: *P6, Pinus tecunumanii; P7, Hieronyma alchorneoides* Allemao; *P12, Pentaclethra macroloba; P1, Virola koschnyi*; *P9, Vochysia ferruginea; and P4, Vochysia guatemalensis.* Not all species listed on the map were included in this study.

Methods

Measurements of soil respiration were initiated in September 2004 in each of the four replicate plots of six plantation types and continued until February 2010 in four of the plantation types. All studies were based on LI-COR automated soil gas flux instruments (LI-COR Biosciences, NE, USA) that were returned to the factory for cleaning and recalibration annually. The specific measurement chambers utilized varied, but they provided fully comparable measurements of in situ soil-CO_2 emission rates, or soil respiration, Rsoil. The study included diel measurements and measurements made one time (survey), during daytime hours. The survey measurements were undertaken to test for significant influences of plantation type (tree species) and time-of-year on the magnitude of soil respiration.

- Soil temperature, soil moisture, ambient air temperature, relative humidity, and ambient CO2 concentrations were measured during the diel and survey measurement periods.
- To test for temporal offsets between leaf production and soil respiration, more than four years of overstory litterfall measurements were made from October 2003 to December 2009.

Soil respiration - diel measurements

Soil CO_2 emissions were measured in individual plots every hour over a total of 52 continuous periods of greater than two days between November 2004 and February 2010 to investigate hourly variability in Rsoil. Measurements were made with a LI-COR 8100 soil CO_2 flux system attached to an 8100-101 long-term chamber that was attached to a deep-charge marine battery, which was back-packed into an experimental plot and then left in place for hourly measurements covering two to three day periods. A single 20-cm diameter, 12-cm tall polyvinyl chloride collar was inserted approximately two cm deep into the surface soil of a plot by carefully cutting through the forest floor with a sharp knife one day prior to measurements. All measurements were at randomly located positions without regard to tree positions. During measurements, the chamber closed tightly over the soil collar for two minutes, and within-chamber CO_2 concentrations were monitored as the chamber headspace circulated through the IRGA (total system volume averaged 7 L). The first 30 s of measurements were ignored to allow for internal mixing to complete. Over the remaining 90 seconds the concentration of CO_2 within the chamber was measured every second, and the rate of change in headspace CO_2 concentrations was used to quantify soil-CO_2 efflux.

The resulting time-series data were analyzed using LI-COR's embedded FV8100 file viewer software. In most cases, exponential fits were utilized

because the rate at which within-chamber CO_2 concentrations increased typically declined through time. Lower fits usually were associated with rain and strong wind gusts. The first measurement collected during each measurement period was discarded because of consistently high ambient CO_2 concentrations that were attributable to human respiration. Due to time commitments to other studies, no diel measurements were made from May through September.

Mineral-soil temperature was measured with a soil thermistor probe (LI-COR part 8150-203). Surface-soil volumetric moisture content was assessed at four locations surrounding the chamber, at the beginning and end of each measurement period, using a Campbell Scientific CS620 Hydrosense system with 12-cm TDR rods. Following successful completion of one measurement the equipment was relocated to a different plot and another measurement period was initiated. All 24 plots were measured at least twice to capture both dry and wet periods. Additional measurements collected in 2004, before sensor malfunctions halted initial measurements, are included (Raich, 2017).

Soil respiration - survey measurements

The survey study involved sampling each of the experimental plots at one time, including reps in all four blocks. The survey measurements were undertaken to test for significant influences of plantation type (tree species) and time-of-year on the magnitude of soil respiration. Measurements were made 66 times over 2004 to 2010, with four replicates per plantation type, four to six plantation types each date in lowland Costa Rica. These were the same plots used for diel measurements.

Measurements were conducted with backpacked instruments and were limited to daytime hours. Altogether, 99.5% of the measurements were collected between 07:30 and 16:30. Sunrise and sunset were at approximately 06:00 and 18:00 every day.

Soil CO_2 emissions in the plantations were measured using a LI-COR 8100 soil CO_2 flux system (LI-COR Environmental, Lincoln, Nebraska, USA, http://www.licor.com/). From 2004 through 2008 measurements were made with an 8100-102 chamber placed on top of 10-cm diameter, 5-cm tall soil collars. There were three to four collars per plot (12-16 collars per species each date), and they were moved to new randomly selected locations every year or whenever they were disturbed. At each collar on each measurement date, soil CO_2 fluxes were monitored every second for 90 seconds. Fluxes were calculated over the final 70 s of chamber closure, using the embedded LI-COR file viewer software, with the first 20 s being excluded to allow for full mixing of the within-chamber atmosphere. The mean flux over the final 70 s usually was based on an exponential fit of the CO_2 concentration over time relationship. Initial measurements included six species, in one plot per block of each.

- Measurements in *Vochysia ferruginea* plots were discontinued after May 2006 because entire trees began falling as a result of butt rot, which seemed to spread among adjacent trees via root grafts.
- Measurements were discontinued in *Pinus patula* plots after March 2008 because trees dropped all their needles and fell apart.

From February 2009 through February 2010 an 8100-103 (20-cm diameter) chamber was utilized, with four 20-cm diameter collars in each of the four plots of each of the remaining four tree species. Within-chamber CO_2 concentrations were monitored every second for four minutes, with the first 40 s being allowed for full mixing of the air within the chamber, and the subsequent 200 s being used to calculate CO_2 emissions. It sometimes took two days to complete measurements in all four blocks. Each measurement cycle began at a randomly selected block to minimize the potential for temporal bias to influence comparisons among blocks and species (Raich, 2017).

Ambient environmental conditions were also made during the survey measurements at each measurement location, following similar protocols as those used in the diel study. At the time of soil respiration measurements, a thermistor probe (LI-COR 8100-201) was inserted 5 cm into the mineral soil approximately 20 cm distant from the measurement collar at three locations, to measure soil temperature. Starting in 2009, soil temperature was also measured at 10 cm depth. After each measurement, a soil moisture sensor was inserted into three locations >20 cm from the chamber, to measure surface-soil water content. Soil moisture in the surface (ca. 10 cm of soil) originally was measured with an ECH_2O Dielectric Aquameter (Model EC-10, Decagon Devices, Inc., Pullman, Washington, USA; http://www.decagon.com/; LI-COR part 8100-202). In 2005 that instrument was replaced with a Campbell 620 Hydrosense water content sensor with 12-cm long probes (Campbell Scientific, Inc., Logan, Utah, USA; http://www.campbellsci.com/), which was used for the remainder of the study.

Litterfall measurements

Litterfall measurements were made from October 2003 to December 2009 and were used to test for temporal offsets between leaf production and soil respiration. Litterfall was measured with four traps per plot that were emptied at the middle and end of each month. Traps had dimensions of 1.3-m x 0.4-m and 2-mm mesh screen bottoms, and were supported about 30 cm above the soil on steel legs. The collected materials, which included branches less than or equal to1-cm in diameter and all non-woody materials, were combined within months to generate a single sample per plot that was sorted into four fractions: branches and bark; overstory leaves; other leaves; and miscellaneous materials (Raich et al., 2007, Valverde-Barrantes 2007). Traps were removed, repaired and repositioned annually (Raich, 2017).

Oven-dry weights on a per-meter-squared per-day basis are provided, with carbon and nitrogen contents (%) where available.

6. Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

Soil CO2 Flux, Moisture, Temperature, and Litterfall, La Selva, Costa Rica, 2003-2010

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
- Telephone: +1 (865) 241-3952

7. References

Fisher, R.F. Amelioration of degraded rain forest soils by plantations of native trees. 1995. Soil Science Society of America Journal 59: 544-549.

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