Lab (A): Soil Gas Exchange
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Overview.
This activity will introduce you to gas exchange measurements using a LiCor 6400 Portable Photosynthesis Machine. You will use the 6400 to conduct soil respiration measurements measurements.

Background.
Relevance of Gas Exchange

The expression "gas exchange" is often used to refer to the uptake and loss of CO_2 and water vapor. In this lab we will focus primarily on plant fluxes of CO_2 by measuring photosynthesis and foliage and soil respiration. We will discuss water vapor flux insofar as it effects the measurement of CO_2 flux.

Measuring photosynthesis makes sense, but you may be wondering: why do we want to measure soil respiration? For one, root respiration accounts for 20-70% of forest soil respiration. Also, soil respiration is a large component of the net carbon balance of an ecosystem. In this lab we will consider how the balance between CO_2 assimilation (i.e. photosynthesis) and CO_2 production (i.e. respiration) from both aboveground and belowground sources determines whether a system is a net sink or source of CO_2.

Using the LiCor for Foliage and Soil Measurements

We will use the same instrument, the LiCor 6400, for foliage and soil measurements by making a few changes in plumbing. The LiCor is an IRGA, an Infrared Gas Analyzer. It measures CO_2 and water vapor concentrations by measuring the amount of infrared radiation that can be transmitted through a gas sample. Both CO_2 and water vapor are strong absorbers of infrared radiation (that is why they are greenhouse gases), and the level of infrared absorption is proportional to their concentrations. Separate detectors for water vapor and CO_2 contain filters that permit only wavelengths unique to each gas to reach the detectors.

To measure photosynthesis, leaves or needles are placed in a gasket-sealed cuvette while they are still attached to a stem. Instruments integrated into the cuvette control and measure light, temperature, and moisture levels. The concentration of CO_2 entering the cuvette can also be controlled.

Air is pumped through the LiCor and split into 2 pathways: one to the leaf cuvette and an attached *sample* IRGA, and the other to a *reference* IRGA. The reference IRGA therefore measures the CO_2 concentration of air that enters the leaf cuvette. The difference in concentration between the sample and reference IRGAs gives the amount of CO_2 taken up the leaf. This amount, multiplied by the air flow rate, gives the rate of photosynthesis in units of μmol CO_2 m^{-2} s^{-1}. This "open system" produces steady-state conditions– i.e new air is continuously pumped through the cuvette so over the course of a measurement the leaf encounters constant levels of incoming CO_2 and H_2O vapor

To measure soil respiration, the LiCor is re-plumbed to a "*closed* system," and only the *sample* IRGA is used. The leaf cuvette is replaced with a 2 liter soil chamber that attaches to the sample IRGA. Soil respiration rate is determined by placing the chamber on the soil surface and measuring the rate of CO_2 accumulation in the chamber over time. The units of soil respiration are also μmol CO_2 m^{-2} s^{-1}. (To calculate soil respiration in a way analogous to photosynthesis, one would have to put soil in a sealed cuvette, but this would not give an *in situ* measurement.)

Because soil respiration rates are generally driven by *molecular diffusion*, it is important not to generate significant pressure differentials during measurement. A change in pressure inside the soil chamber would effectively push or suck air from the soil. For this reason, during soil measurements the pump is only used for a few moments rather than continuously. The pump is used to move CO_2 free air into the soil chamber and draw down the CO_2 concentration below ambient levels. Then the pump is turned off and the rate of CO_2 accumulation is measured as the CO_2 concentration in the chamber approaches ambient levels. In contrast, photosynthesis rates are measured in a flow-through system, with the pump constantly moving new air through the sample and reference IRGAs.

This synopsis and the reading in the LiCor manual should provide you with a good understanding of how the LiCor works in both foliage and soil applications.

Specific learning objectives. After you complete this laboratory activity and the write-up after the lab, you should be able to:

Soil Respiration

1. Be able to explain the fundamental principles of how closed-chamber gas exchange measurements work.
2. Be able to measure soil respiration with the LiCor-6400.
2. Be able to "scale up" from chamber measurements to estimate tree-level respiration rates.

Materials/supplies needed:

1. Pencil
2. Hard writing surface

Lab Activities.

Demonstration of foliar gas exchange measurements

You will each take a turn making foliar gas exchange measurements.

LiCor 6400 Setup

- Commands in the "MEASUREMENTS" menu are made from 6 sub-menus (or "levels") numbered at the bottom left of screen. Levels may be selected by scrolling with "LABEL" keys or by hitting 1-6. Within the different levels, commands are made by hitting command keys (f1, f2, etc)
- Open a log file and name file such as "your name" (f1 Level 1)

Respiration Measurements

You will each take a turn making a soil respiration measurement.

A. **Open a new log file**

Open a new log file (**f1** level 1) and type in an appropriate name.

B. **Turn prompts on**

Turn prompts on to be prompted for the collar ID (**f4** level 3).

C. **Position the ring stop**

Move the metal ring on the outside of the soil chamber up or down so that when the chamber is placed inside a soil collar the chamber will be 0.5-1.5cm above the soil surface. Tighten the thumb screws well so it doesn't slip!

D. **Insert the soil temperature probe**

Insert the probe near the collar but out of the way of where the chamber needs to be. Be gentle as it bends easily.

E. **Calculate the "insertion depth"**

- This number will be used to recalculate the chamber volume, which is part of the CO_2 flux calculation.
- You need to determine the distance between the chamber rim and the soil surface. First measure the height of the soil collar above the soil, then the distance between the rim of the chamber and the foam gasket, and find the difference between the two measures. Since the soil surface is uneven, measure the height of the soil collar in a few locations and take an approximate average.
- With the bottom row of menu options on level 7, press F5 to enter the insertion depth. **Enter your measurement as a negative value** because with soil collars chamber sits above the soil surface.

E. **Determine the ambient CO_2 concentration**

- Lay the chamber on its side next to the collar, aiming upslope or upwind if possible to take advantage of air circulation.
- When the readings have stabilized, enter the ambient concentration in "Target" (**f1** level 7). You will then be prompted for ΔCO_2 ("Delta"), which is the range around ambient where you want to measure respiration. Entering 10 means respiration measurements will begin at 10ppm below ambient CO_2 and will end 10ppm above ambient. Enter 10 to start, and if respiration rates are very slow you can later switch to 5.

F. **Start the measurement**

- Press Start (**f3** level 7). If you have Prompts ON, you will get those now. The measurement cycle will begin.
- Record the location, the starting time, and the final soil temperature, and all 3 flux rates.

G. **Carefully remove the soil chamber without pulling out the collar.**

Data Sheet for Gas Exchange Lab

Soil Respiration Measurements

Obs	Plot#	Efflux	Ambient	Tsoil_C	notes

Sapwood Area (m^2):	
Soil Area (m^2):	
Tree Leaf Area (1-sided) (m^2):	

Additional notes: