Lab 8: Soil respiration using portable chamber

Respiration is the 2nd most important carbon flux in ecosystems following GPP (gross primary productivity); and soil respiration makes up 40 to 80% of ecosystem respiration. The objective of this lab is to better understand how environmental constraints (temperature and moisture) and management, effect soil respiration.

11.1 Symbols, constants and units

Symbol	Name	units	notes
T_s	Soil temperature	^oC (or K)	measured
T_{ref}	Reference soil temperature	^oC (or K)	measured
V	Volume of chamber	0.00065363 m^3	constant
A	Area of ground covered by chamber	0.007854 m^2	constant
Q10	Ecosystem respiration	Dimensionless	Equation 5
ρ	Molar density of air	40 mol m^{-3}	constant
GEP	Gross ecosystem photosynthesis	µmol m^{-2} s^{-1}	Equation 1
NEP	Net ecosystem productivity	µmol m^{-2} s^{-1}	Equation 1
NEE	Net ecosystem exchange	µmol m^{-2} s^{-1}	Equation 2
R_e	Ecosystem respiration	µmol m^{-2} s^{-1}	
R_s	Soil respiration	µmol m^{-2} s^{-1}	Equation 4
R_h	Heterotrophic respiration	µmol m^{-2} s^{-1}	
R_{rhiz}	Rhizosphere respiration	µmol m^{-2} s^{-1}	
F	Soil Co_2 efflux	µmol m^{-2} s^{-1}	Equation 6

11.2 Theory

Carbon sequestration at the ecosystem scale, also known as Net Ecosystem Productivity (NEP) is the difference between photosynthesis and respiration and can be written as:

$$NEP = GEP - R_e \quad [1]$$

Thus when NEP is positive (GEP > R_e) the ecosystem is gaining CO_2. Alternatively, the net exchange of CO_2 between terrestrial ecosystems and the atmosphere, called net ecosystem exchange (NEE), is the difference between ecosystem respiration R_e and gross ecosystem photosynthesis (GEP):

$$NEE = R_e - GEP \quad [2]$$

Thus when NEE is positive (R_e > GEP) the atmosphere is gaining CO_2 (i.e. ecosystem is losing CO_2). NEP is then the net uptake of CO2 by the ecosystem from the atmosphere (a term used by biologists), while NEE (the term used by biometeorologists) is:

$$NEE = - NEP \quad [3]$$

Soil respiration (R_s) can account for as much as 80% of ecosystem respiration, and results in the efflux of CO_2 from the soil. R_s is composed of the CO_2 produced by microbial decomposition of soil organic matter (SOM) – heterotropohic respiration (R_h), and by rhizosphere respiration (R_{rhiz}) associated with root respiration + mychorrizal and microbes in the rhizosphere fed by root exudates.

$$R_s = R_h + R_{rhiz} \quad [4]$$

Soil temperature (T_s) followed by soil moisture (Θ) are the most important environmental factors affecting R_e. R_e increases exponentially with T_s, often expressed as:

$$R = R_{ref}\, Q_{10}^{\left(\frac{T_s - T_{ref}}{10}\right)} \quad [5]$$

where: R_{ref} is R_e at a reference temperature T_{ref}, usually 10 ^oC; and Q_{10} is the relative increase in R_e for a 10 degree increase in T. Q_{10} is about 2 in many biological processes,

but may be has high as 3 for R_e and R_s. This sensitivity is particularly important in predicting the impacts of global warming on decomposition rates, but is dependent on substrate quantity and quality, soil temperature and soil moisture.

A widely used method for measuring R_s is the closed or static chamber method. In this method the rate of CO_2 concentration in a chamber placed on the soil surface is used to determine the soil CO_2 efflux (F). This is a good measure of F as little respired CO_2 accumulates in the soil. Thus F can be calculated using:

$$F = \frac{\rho V}{A}\frac{dC}{dt} \qquad [6]$$

where: ρ is the molar density of air (40 mol m^{-3}), V is the volume of the chamber (m^3), A is the area of ground covered by the chamber (m^2), dCO_2/dt is the rate of increase in CO_2 concentration, and F is in units of μmol m^{-2} s^{-1}. If the chamber is kept on the soil < 2 minutes, dCO_2/dt is almost constant (linear); that is the increase in CO_2 concentration does not significantly suppress CO_2 efflux. As the CO_2 concentration changes during the measurement, this method is described as non-steady state.

Recall that NEE = R_e – GEP. So if there is vegetation in your chamber you are measuring NEE. If there is not vegetation GEP → 0 and $R_e = R_s$.

11.3 Objectives

To determine the sensitivity of R_s, by comparing the magnitude of F from bare agricultural soil, (both fertilized and unfertilized), and a soil under a cover crop (both fertilized and unfertilized). Four containers of soils have been collected from the Delta region, which are Gleysolic soils with silty clay loam texture. Two containers have been seeded with a typical winter cover crop in the region and two have been left bare. One bare soil and one cover cropped soil have been fertilized with urea fertilizer (46-0-0). All soils have been watered equally to obtain a soil volumetric water content close to field capacity (25-35%).

11.4 Laboratory Procedure

1. Allow the instructor/assistant to bring up the soil greenhouse gas software.
2. Plug in your Vaisala GMP252 Carbon dioxide probe into an electrical socket.
3. Wait 1-2 minutes for the sensor to start measuring, and for the screen to appear on the projector screen.
4. Ensure that the Vaisala GMP252 Carbon dioxide probe's chamber opening is flat on the table. Allow the probe a sufficient amount of time to equilibrate to atmospheric conditions – this can be recognized by a flat reading approximately 400-500 ppm for 2-3 minutes. This typically can take 4-5 minutes from startup of the probe.
5. At the top of the measurement sheet record the soil treatment you are working on.
6. Using the display screen
    a. Using the rubber end of the pencil you can <u>gently</u> tap on the display to perform certain functions.
        i. **Resize the graph** – tapping in the top left-hand corner

ii. **Refresh the graph** – tapping in the top right-hand corner

iii. **Obtain an estimate flux** – tapping at the start of the increase in the CO2 graph will allow you to select a point. It will then generate a line and slope automatically using a 60 second time interval. This slope is an approximate value for the flux of CO2.

7. Once the probe has equilibrated, record the ppm reading on your datasheet (this is your initial value at time 0). Set up a timer on your smartphone or a stopwatch.
8. Gently pick the sensor up and place it onto the soil gas collar that has already been inserted into the soil. Be sure to go slow, so as to not create a significant pressure differential inside the chamber. Simultaneously start your timer.
9. Every 30 seconds, record the concentration of carbon dioxide (ppm) displayed on the CO_2 sensor screen for 180 seconds.

10. After 180 seconds, remove the chamber from the collar and place the chamber on the counter with the open side facing out and away from people, allow it to reach equilibrium again (3-4 minutes). Your reading value should approach your initial value.
11. Using the eraser end of the pencil, gently tap on the screen at the start of the increase in CO_2 concentration where there is a relatively straight line. This will give you an approximate CO_2 flux. You can tap on the top left hand of the screen to resize the curve if needed, and refresh the screen by tapping on the top right hand side. Record this readout flux value from the sensor. You will need to get 3 relatively consistent readings for each soil/vegetation/fertilizer combination (i.e. at each station).
12. Insert one thermometer approximately 5 cm into the soil and record the temperature after 3 minutes.
13. Leave one thermometer on the counter, and record the temperature of the air at 3 minutes.
14. Use the TDR to measure soil volumetric water content at 3 points around the soil gas collar. Ensure that the measurement mode is set to the correct soil type for your experiment.
15. Flip the sensor flat onto the table for 2-3 minutes until it reaches a constant measurement. Note: the equilibrated concentration of CO_2 may increase slightly in the room due to the amount of people in the room respiring. Use a fan to assist the small fan in the unit to re-circulate air into the headspace of the chamber if necessary.
16. Repeat steps 7-15 on each soil treatment a minimum of 3 times in order to obtain an average gas flux measurement. Note if there is inconsistency in your flux values determined from the readout screen, you will need to repeat measurements > 3 times.
17. After obtaining an average CO_2 flux for your soil (bare/vegetated, +/- fertilizer) all groups will rotate to the next station and repeat measurements for that soil.

11.5 Calculations

1. Plot the change in ppm versus time (s) for each of your 4 soils (and replicates), and calculate the slope $\Delta CO_2/\Delta t$ (ppm CO_2 s^{-1})

For each soil, convert the measured CO_2 increase (ppm CO_2 s^{-1}), to flux density, F (µmol m^{-2} s^{-1}) using equation 6. Obtain values for ρ, V and A from section 2.1 symbols, values and units.

Complete data sheet (and attached to your assignment)

11.6 References

Davidson E.A. Janssens I.A. 2006. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Nature 440(9): 165-173.

Jassal R. Black A. Novak M. Morgenstern K. Nesic Z. Gaumont-Guay D. 2005. Relationship between soil CO2 concentrations and forest-floor CO2 effluxes. Agricultural and Forest Meteorology 130:176-192.

Jassal R. Black A. Novak M. Gaumont-Guay D. Nesic Z. 2008. Effect of soil water stress on soil respiration and its temperature sensitivity in an 18-year-old temperate Douglas-fir stand. Global Change Biology 14(6): 1305-1318.

Soil Respiration Lab								
Reading Number	Covered Soil		Bare Soil		Covered Soil With Fertilizer		Bare Soil With Fertilizer	
	time (s)	CO2 (ppm)	time (s)	CO2 (ppm)	time (s)	CO2 (ppm)	time (s)	CO2 (ppm)
1	0		0		0		0	
	30		30		30		30	
	60		60		60		60	
	90		90		90		90	
	120		120		120		120	
	150		150		150		150	
	180		180		180		180	
	Slope on display:		Slope on display:		Slope on display:		Slope on display:	
	Slope calculation:		Slope calculation:		Slope calculation:		Slope calculation:	
2	0		0		0		0	
	30		30		30		30	
	60		60		60		60	
	90		90		90		90	
	120		120		120		120	
	150		150		150		150	
	180		180		180		180	
	Slope on display:		Slope on display:		Slope on display:		Slope on display:	
	Slope calculation:		Slope calculation:		Slope calculation:		Slope calculation:	
3	0		0		0		0	
	30		30		30		30	
	60		60		60		60	
	90		90		90		90	
	120		120		120		120	
	150		150		150		150	
	180		180		180		180	
	Slope on display:		Slope on display:		Slope on display:		Slope on display:	
	Slope calculation:		Slope calculation:		Slope calculation:		Slope calculation:	