

SLIDE 1:

Thanks, Ashlee. Today's webinar topic is titled Advantages of Automated Soil CO₂ measurements. This is part three in a four part series about Soil CO₂ flux.

SLIDE 2:

Before we get started, let's briefly review the first two webinars in this series. Part one was an introduction to soil CO₂ flux. To view any of these past webinars, you can visit the URL below.

SLIDE 3:

Part one highlighted three main themes regarding soil CO₂ flux. Where does soil CO₂ flux come from? And, in the first webinar we talked about autotrophic respiration, which are those organisms that are able to make energy containing organic molecules from inorganic raw material, by using basic energy sources such as sunlight. Plants would be a good example of autotrophs. All other organisms must make use of food that comes from other organisms in the form of fats, carbohydrates, and proteins. These organisms, which feed on others, are called heterotrophs. Soil CO₂ flux also comes from respiration of soil fauna and in some cases inorganic carbonates.

We also talked about what effects soil CO₂ production, such as the biology. The biology in the form of the substrate supply, which is photosynthesis. Also temperature of the (Q10), where for every ten degrees centigrade increase, biological reactions double. Soil moisture or lack thereof can also have a huge impact on the flux.

Finally, chemistry, the composition of the soil is also an important factor in the flux rate. In that first webinar, the last thing we discussed was what effects soil CO₂ movement, such as the diffusion gradient, pressure and precipitation events.

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SLIDE 4:

The second webinar focused on techniques for soil CO₂ flux measurements.

SLIDE 5:

In the second webinar, we discussed the different methods to measure soil CO₂ flux, and highlighted the six requirements for making an accurate soil CO₂ flux measurement. Those six requirements are listed on this slide; the first one being where we do not disturb the soil, so the CO₂ in the soil cannot be disturbed. The second requirement is the CO₂ in the chamber is equal to CO₂ in the air. The third requirement is the chamber pressure must follow ambient, so you need an adequate vent. The fourth requirement is good mixing, but not excessive mixing. The fifth requirement was to have no disturbance to the soil moisture, temperature or radiation balance. And finally, you need adequate sampling and space and time. This final requirement is what we will highlight in today's webinar as well.

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Again, today's webinar is titled Advantages of Automated Soil CO₂ Flux Measurements.

SLIDE 7:

What do we mean by advantages of automated soil CO₂ measurements? Automated in this context can mean two things; it can mean an automated chamber which closes down on the soil collar without the help of an individual, or in the case of this webinar, automated – we'll mainly refer to an automated system that is used in the field unattended.

SLIDE 8:

What will we discuss in this webinar? We wanna talk about why getting the right answer is important.

We're gonna talk about the differences between survey and long-term soil CO₂ flux measurements.

We're gonna talk about how to identify trends in discreet but important gas exchange events in long-term data sets. And finally, we're gonna talk about how multiplex measurements can help identify sources of variation in a study site.

SLIDE 9:

Why is understanding soil flux important in an ecosystem? It is a major component of the carbon balance, and occurs in the form of microbial and litter respiration. And you can see from this slide, we show the entire canopy carbon balance. Soil CO₂ flux is an important part of an entire balance. And you can see the root respiration, microbial respiration and litter respiration all are a function of soil CO₂ flux.

SLIDE 10:

Scientists want to know the environmental factors that affect soil CO₂ flux, such as soil temperature, moisture, organic matter content, rain events and other environmental factors. They also want to understand how soil flux relates to biological processes such as photosynthesis and leaf area index. In order to do this effectively, they must have high spatial and temporal resolution.

SLIDE 11 (POLL 1):

Before we get further into the webinar, we're gonna ask a poll a question. The poll question is, do you currently take soil CO₂ flux measurements, and if so what type? You have two choices, no or yes. And if it is yes, you can answer survey or manual, which is basically walking around with a survey chamber taking multiple measurements on multiple collars. Or automated long-term diurnal measurements, where you have an automated system out in the field, or both. Take a moment to review your answer. Alright, thank you for your answers. Okay, moving on.

SLIDE 12:

Like I mentioned earlier, soil flux, or respiration as it is commonly called, is a very difficult measurement to make. Diffusion from a porous medium is sensitive to feedback from chamber head space CO₂ concentration. The instant a chamber closes down, the diffusion slows down to the concentration gradient making it imperative to have the right calculation method for obtaining a proper flux rate. Diffusion also means the system is sensitive to pressure and wind effects. Soil respiration is also highly variable in time. Which means it requires frequent sampling to effectively understand the total carbon

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output in any location. It is also highly variable in space. Even in the data I will show you later, you will see how variable the flux can be in what appears to be a very homogenous, agricultural field. To accurately measure the amount of CO₂ respiration in an ecosystem, multiple collars should be measured. Since multiple measurements are needed, they need to occur quickly. Soil respiration measurements need to be fast and accurate.

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Why do we need to get it right? This slide here shows the importance of getting the right answer when it comes to soil CO₂ flux. Net ecosystem productivity, or NEP as it is commonly called, is the difference between two large numbers; gross primary productivity minus ecosystem respiration. For any ecosystems, net ecosystem productivity is small or near zero on an annual basis and can even change sign from year-to-year. For example, growing conditions may be ideal one year, in that year rainfall timing and temperatures may be such that maximize photosynthesis and growth, making the net ecosystem productivity positive. That next year could be a drought in which growth is limited during the growing system, yet respiration exceeds growth and you have a negative year for gross primary productivity. Soil respiration is often a large fraction of ecosystem respiration. Some papers have soil respiration well over fifty percent and into ninety percent of ecosystem respiration. And you can see those papers listed here. Since NEP is small from year-to-year and can even change sign, it is very important to estimate ecosystem respiration accurately, and soil respiration or soil CO₂ flux is a critical component of this equation.

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Now that we have talked about the importance of understanding and making an accurate soil CO₂ flux measurement, let's discuss the measurement methods in more detail. Survey measurements answer the spatial variability associated with soil CO₂ flux, and require a person to sample multiple collars at whatever intervals decided.

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These survey or manual measurements require an analyzer, pump and data logger shown in the yellow box in this diagram; and a survey chamber shown on the left.

SLIDE 16:

How many samples should be taken? As you can see from this diagram, focusing only on survey measurements is simply a balance between how many samples you take versus the percent uncertainty you can live with. The graph in this slide shows the number of samples averaged against the uncertainty of the mean for sites with coefficients or variation ranging from five percent to a hundred percent. These uncertainties were calculated using standard statistical theory. Even for a relatively uniform site with a CV of ten percent, such as agronomic plots, as many as fifteen flux readings may be required to obtain a mean value with an uncertainty of about five percent. For sites with greater variability, an even larger number of measurements would be required.

SLIDE 17:

From the previous plot, you can see the challenges taking enough samples both spatially and diurnally. Researchers have often suggested augmenting the high temporal resolution of long-term automated readings shown here with survey chamber readings. Long-term measurements help understand diurnal changes associated with CO₂ flux. In this case, a researcher may use a single long-term chamber to get a handle on the diurnal cycle, and take multiple survey or manual measurements nearby to better understand the spatial differences.

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A more effective solution is to take multiple automated, unattended measurements using a system that offers both a spatial and diurnal component. The multiplexed system shown here provides multiple chambers that are running sequentially. These types of measurements can run for weeks, months and even years at a time; and collect enough data over time and space to accurately estimate the important

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component of ecosystem respiration that we discussed earlier. So an accurate assessment of net ecosystem productivity can be known.

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The multiplexed system requires an analyzer control unit that houses the infrared gas analyzer, data logger and pump. It connects to a multiplexed unit whose job it is to move from one chamber to the next, sequentially sampling CO₂ fluxes. Up to sixteen chambers can be connected at this type of unit.

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What can we learn from automated multiplex soil CO₂ measurements? The data I'm about to show, was taken at a cornfield in mid-September. Eight chambers were deployed within the corn row, and eight chambers were connected between the corn row for a ten day period.

SLIDE 21:

Only ten days of deployment and what did we learn? The red line in this graph is temperature. The dark circles are chambers within the row located closest to the plants. And the open circles are chambers between the corn rows located further from the plants. You can see the difference respiration makes on soil CO₂ flux, since the chambers closest to the roots give the highest fluxes over the ten day period. Rain also does interesting things to soil CO₂ flux. Late on day two seventy one, there was a small rain event. And it was just enough to displace the CO₂ in the pores and cause a temporary spike in the fluxes. Had this rain event prolonged, you would have seen the initial displacement spike, and then a lowering to the flux due to saturation of the soil where the CO₂ could not escape. I will show data that represents that later in the webinar. Finally, you can see a nice diurnal pattern to the flux up until the frost event on day two seventy two. This frost essentially killed the plants. And despite the warming temperatures later that next week, the diurnal cycle driven by the plants simply went away. Data like this allows researchers to understand soil carbon dynamics as conditions changed throughout the season, and year-to-year.

SLIDE 22:

The next season, the same field was planted soybeans. As corn/soybean rotations are typical in the Midwest. These pictures show the multiplex system at work, from soon after planting all the way prior to harvest.

SLIDE 23:

This next slide looks pretty busy. But I will take some time to explain what all the variables mean. For that soybean season, from the pictures I showed before, we were able to install the system approximately one month prior to planting all the way till harvest. The graph at the top is soil temperature at five centimeters deep as well as rainfall. In both charts, the black line with dots represents chamber measurements between the soybean rows. And the red line with dots, represent chamber measurements within the soybean rows. As the growing season progressed, you can see how important diurnal measurements are as flux rates changed fourfold, depending on the conditions. Along with temperature, rain events are very interesting. You can see the rates drop soon after the two large rain events. Rain and soil flux can be very unpredictable. Depending on the soil type, surface matter and other conditions, rain can either enhance or decrease the fluxes. In the case above, you can see a quick drop in soil flux after the two large rain events. With large rain events, the pore spaces become very saturated to the point they no longer let gases out of the soil. Over the next few days as the soil dries out, the rates are typically enhanced due to increased microbial activity, but sudden drops are noticeable due to saturation. I'll discuss more on rain and fluxes later in the talk.

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After the soybean harvest, we redeployed the chambers the following spring, and ran the system in a cornfield from planting through harvest.

SLIDE 25:

And you can see the pictures shown here. Again, another busy slide but we're showing data once an

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hour, with sixteen chambers throughout the entire growing season. In this seasonal data set, we see a nice diurnal pattern to the CO₂ flux at the heart of the growing season, and a breakdown of that diurnal pattern once the plants were removed from the field. The nice thing about large multi-chambered data sets, is the ability to step back and look at the big picture, shown here of the entire corn growing season. With data from each chamber every hour during the season, we can really start to see patterns and break down differences between chambers, and begin to explain why even in a seemingly homogenous agricultural field, fluxes from chamber to chamber vary greatly.

SLIDE 26:

Here is a breakdown of the data set I just showed. In this slide we have a ten day period in June of all sixteen chambers. The blue line represents mean temperature, and the red dots indicate data from all sixteen chambers. To the casual observer, it looks like our system broke down on day a hundred and sixty three. How could we suddenly have had fluxes triple in some cases, stay the same in others, and even drop? How could all of this happen in an instant when the fluxes were so tightly grouped the previous few days? Initially, we even had doubts about the system. But after reviewing – after looking at the system, we maintain confidence that this was indeed something natural, and we needed to investigate it further. As we looked at the weather data, we noticed that the previous couple of weeks before day a hundred and sixty three were rain free and hot. The fluxes during that time had varied from one to just over four micromoles per meter squared per second. On day a hundred and sixty three we received over an inch of rain. How does an inch of rain enhance and change the sign or the CO₂ fluxes all at the same time with chambers just a few meters apart from each other?

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In this slide, we're gonna see the answer to that question. Right after we reviewed the previous data set, I had pictures taken of the collars. Although the field seemed uniform and homogenous, the debris field from the previous harvest was anything but. We found the fluxes dropped during that rain event with the

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collars that had little or no debris. And the collars that were full of debris had fluxes that had increased threefold or more. The fluxes remain consistent with collars that had some debris. It turns out that the collars with no debris had saturated to a point that little or no CO₂ was being released. The collars with enhanced fluxes most likely saturated as well, but the microbes and the refuse immediately became active and started breaking down the debris in the collar, which in turn sky rocketed the flux rates. So here we have a multiplex system, with a diameter of thirty meters, the chambers spread across. And we see fluxes in an instant change sign increase and do all sorts of crazy things, all because of a rain event. So, again, reiterating the importance of taking automated flux measurements to see these types of events in the data.

SLIDE 28:

To further prove this concept, we brought dry corn stover, or residue, as the debris is commonly called back to the lab and placed it in a sealed collar. Over the course of a few days, we watched the fluxes increase after moisture was applied and decrease over time. We did this three times in a twenty-five day period to prove that moisture applied to a dry substrate, such as corn residue, will instantly increase the fluxes. Data sets like the ones had I previously shown are made much easier with automated long-term measurements. The ability to capture seasonal data and break it down as conditions changed throughout the year, offers tremendous potential to discover new opportunities and advance the science of understanding the natural carbon cycle.

SLIDE 29:

With seasonal data sets, one can begin to estimate the total CO₂ admitted from a particular ecosystem. In the cases on this slide, we focused on the growing season in which most CO₂ is emitted, and is correlated nicely with LAI which is leaf area index and photosynthesis. Like I mentioned in the previous slide, the difference between gross primary production and ecosystem respiration is small, so frequent flux measurements over the course of a season is essential in capturing this information.

SLIDE 30:

The data sets shown for both corn and soybeans in this webinar reflect measurements taken every hour of every day. The slide here shows how much error can occur if that measurement interval is extended. If manual or survey measurements were replaced with the frequent automated long-term measurements, one would assume that data would not be taken as frequently, thus increasing your percent air and flux estimation over the course of the season. If that percent air is higher than the gross primary productivity minus the ecosystem respiration, the estimates of carbon exchange may be off by a sign. In other words, if the number is already close to zero, either positive or negative, the error in miscalculated in the real fluxes can change whether you think the system is a net source or sink of CO₂.

SLIDE 31:

This next slide just reiterates that same point. The net ecosystem productivity is the difference of two very large numbers. With soil CO₂ flux being the largest component of ecosystem respiration, it is imperative to be as precise and accurate as possible with the real numbers. The same can be true when trying to estimate gross primary productivity with photosynthesis and leaf area measurements. These numbers and estimates need to be right.

SLIDE 32:

So what is the take home message in today's webinar? We can summarize this webinar with three very important points. Point one being that soil CO₂ flux varies widely in space. It's essential to perform fast measurements and assure adequate replication. Point two, soil CO₂ flux varies diurnally over the season. We showed a couple of large data sets, both with soybean and a cornfield that showed just how variable soil CO₂ flux can be, even in a very homogenous setting such as an agricultural field. Point three, it is important to get the measurements right. Small percent errors create large biases in carbon balances and budgets. We showed examples of that when we talked about net ecosystem productivity, and just how big soil respiration becomes a factor in trying to understand total productivity in of an ecosystem.

CLOSING:

R: That concludes today's webinar. I'm gonna turn it over to Ashlee to see if we have any questions. Ashlee?

A: Thanks, Rod. Our panelists have been taking most of the questions throughout the webinar, but I do have a couple for you. The first question is, how long does it take to measure one sample?

R: Alright, that's a common question we get, Ashlee. One sample means taking one measurement on one individual collar. Whether that's with a survey chamber or a long-term chamber used for those long-term data sets. It takes about two minutes to do a sample on an individual collar.

A: Thanks, Rod. The other question I have is, is there a rule for collar insertion depth?

R: There is real no set rule for collar insertion depth. We do find that it's important to try and avoid breaking roots. So, basically, you wanna install the collar deep enough to where it seals, but shallow enough to where you're not shearing roots off so it doesn't have a significant impact on your soil flux rates.

A: Thanks, Rod. That's really all the questions that I have. Is there anything else?

R: Yeah. I do have one more slide. Again, I hope you enjoyed today's webinar. I would just like to bring it to your attention that we do have the fourth part of our webinar series coming up in the next couple of months. This fourth webinar will help you understand and appreciate how simple data filtering can be with such large seasonal data sets. The talk will focus on the quality assurance and quality control of both large and small data sets. Thank you for attending.

A: Thanks, Rod. Our recording of this webinar will be available in a couple of days. So watch your email for more information about how to access that. And I do believe that there will probably be more

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information as well about attending the next webinar in this series. So just keep an eye on your email, and we'll get you more information soon.