Case Studies of Greenhouse Gas Flux Measurements

In recent years, the advent of reliable, robust, field-portable gas analysers has made possible a rapid expansion in greenhouse gas exchange measurements and networks for sharing flux data. This article features four case studies of ecosystem-scale and soil surface greenhouse gas flux measurements. From biofuel and wetlands research, to soil remediation and land reclamation, these case studies show how greenhouse gas flux measurements are making an impact.

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Greenhouse gas (GHG) flux measurement systems are used to evaluate the impact of industrial and land management practices on GHG emissions and uptake. Emissions and uptake can be compared to determine whether a particular site—over the course of a known time period—acts as a source or sink for the measured gases. These systems can be designed to measure only soil flux or an ecosystem-scale gas flux. Flux measurements are used in numerous applications including land reclamation, soil remediation, landfills, urban studies, wetlands, biofuels, and ecological research. Specialised applications include measurement of crop evapo-transpiration to determine irrigation schedules or water use efficiency. This article introduces two types of gas flux measurement followed by four case studies and a look at GHG flux networks.

Soil Surface Gas Flux Measurement

Soil surface gas flux systems measure gas flux across the soil surface. LI-COR's LI-8100A Automated Soil CO_2 Flux System measures CO_2 flux using enclosed chambers placed directly over the soil. The LI-8100A System can track changes in soil CO_2 flux over time and space. The LI-8100A System addresses critical considerations for soil surface flux measurement—proper mixing to avoid stagnant air pockets, minimal disturbance of environmental conditions affecting CO_2 production and transport, data processing to account for the altered diffusion gradient caused by covering the soil, and a patented vent design for equalising pressure under both windy and calm conditions.

Ecosystem-Scale Gas Flux Measurement

Ecosystem-scale gas flux measurement systems measure the exchange of gases between ecosystems and the atmosphere. Common measurements include CO_2, H_2O, and energy flux. The eddy covariance method is a proven technique for ecosystem-scale gas flux measurement. It uses simultaneous high-speed data from sonic anemometers and gas analysers. With the introduction of low-power, portable analysers; such as LI-COR's LI-7700 Open Path Methane Analyser, methane flux capability is being added to many eddy covariance towers.

Case Study 1: Bioenergy Crops

Greenhouse gas flux measurements can help evaluate bioenergy crops. Researchers at the University of Illinois are engaged in a long-term ongoing study that seeks to quantify the water, nitrogen, and carbon budgets in large plots of Miscanthus (M. x giganteus), switchgrass, restored prairie, and a control (a corn, corn, soybean rotation). The research site in central Illinois enjoys fertile soils, warm summers, cold winters, and sufficient rainfall for rain-fed corn and soybean production. CO_2 fluxes are monitored nearly continuously. "These measurements," says researcher Michael Masters, "are an important part of our effort to completely close the carbon budget in each of these systems. In other words, we'd like to be able to quantify every pool and flux of carbon in order to determine the future climate change implications of changes in species composition that may result from bioenergy production." The study is now in its sixth year. Early results are promising (Zeri et al., 2011 and Anderson-Teixeira et al., 2013), indicating greater belowground carbon allocation in the three bioenergy cropping systems compared to corn and soybeans.

Primary research tools include the LI-7500A, measuring ecosystem-scale CO_2 and water vapour flux as part of an eddy covariance system. Four LI-8100 Automated Soil CO_2 Flux Systems are used for measuring soil respiration. Each system includes an LI-8150 Multiplexer unit with four automated soil gas flux chambers for making long-term diurnal measurements. In addition, multiple LI-8100 Analyser Control Units and chambers are used to make quick survey measurements to better gauge the spatial variability of soil respiration.

Case Study 2: Restored Wetlands

Greenhouse gas flux measurements can help researchers evaluate the climate change implications of wetland restoration. Dr. Karina Schäfer, Assistant Professor of Ecosystem Ecology at Rutgers University, studies urban wetlands in a temperate climate. Schäfer's three study sites include a restored tidal salt marsh in New Jersey and a constructed freshwater wetland in Ohio. Her eddy covariance systems include the LI-7700 Open Path CH_4 Analyser and the LI-7500A Open Path CO_2/H_2O Analyser. Measurements began over two years ago. In addition, LI-COR's LI-6400XT Portable Photosynthesis System is used for studying plants.

Dr. Schäfer's research shows the complexity of wetland methane emissions and the drivers of methane flux. For example, plant species composition and saltwater incursion from tides both appear to affect methane emissions. In addition, restored wetlands give off methane at different rates than naturally occurring wetlands, perhaps due to differences in carbon accumulation in soils.

Case Study 3: Soil Remediation

Soil CO_2 flux measurements can help evaluate petroleum spill sites. Researchers at the University of British Columbia are using CO_2 efflux (emissions) at the ground level as a proxy for the overall rate of subsurface biodegradation of contaminates such as crude oil. Biodegradation is an important component of Source Zone Natural Attenuation, a proposed method for cleaning up spill sites. A research study (Sihota et al., 2011) confirmed the ability of the LI-8100A Automated Soil CO_2 Flux System to distinguish between the rates of natural CO_2 efflux and efflux resulting from contaminant degradation. Results also show the contaminated zone can be delineated with CO_2 efflux measurements. The study site is within a shallow glacial outwash aquifer near Bemidji, Minnesota. A crude oil pipeline rupture contaminated the site in 1979. The LI-8100A system is being used in both survey and automated, multiplexed (4 chamber) configurations. "The instrumentation," says researcher Natasha Sihota, "is providing key

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LI-COR's LI-8100A Automated Soil CO_2 Flux System deployed at a land reclamation site in the Athabasca Oil Sands Region of northern Alberta, Canada.

information on the spatial distribution and temporal trends in gas emissions at our study sites."

Researchers have found the LI-8100A System to be quite versatile. "In addition to evaluating gas emissions above crude oil spills," says Sihota, "we are using the LI-8100A System to monitor gas effluxes above ethanol-blended fuel spill sites. We are also developing laboratory experiments where we will use the LI-8100A System to monitor gas emissions." Samples for laboratory gas analyses are extracted from the chamber head space. In addition, an optional GPS accessory is used for adding the location's coordinate information.

Case Study 4: Land Reclamation

Soil CO_2 flux measurements can help evaluate the effectiveness of land reclamation strategies following surface mining. Researchers from Alberta Innovates – Technology Futures have been measuring soil respiration to help quantify carbon dynamics and net ecosystem productivity in landscapes affected by oil sands mining. The study area is in the Athabasca Oil Sands Region of northern Alberta, Canada. Natural vegetation includes spruce, aspen, poplar, birch and pine trees and is typical of the Boreal forest region. Published results (B.L. Drozdowski, et al., 2010) show that carbon losses were nearly balanced by inputs in the early years following revegetation of mined lands, indicating a transition toward carbon-sink status.

This study involved the use of the LI-8100 Automated Soil CO_2 Flux System for making one-minute survey measurements every four hours between May and October at several sites in 2008 and 2009. In addition, long term soil respiration measurements were made using LI-8100 systems equipped with LI-8150 Multiplexer units.

Flux Networks

When GHG flux data from eddy covariance installations around the world are shared and standardised, it provides scientists a better picture of the global carbon cycle, in addition to providing data for validating remote sensing efforts. Several networks have been organised for sharing data, usually focusing on carbon dioxide, water vapour, and energy exchanges. Sharing of data is made easier by the fact that 90% of CO_2 flux towers worldwide use LI-COR gas analysers, including major flux networks such as Fluxnet, Ameriflux, AsiaFlux, ICOS, GCP, Carbo-Africa, ThaiFlux, ChinaFlux, ILTER, JapanFlux, and OZFlux. Worldwide methane flux data is more limited, but the introduction of field-ready, low power, high-speed analysers, such as LI-COR's LI-7700 Open Path Methane Analyser, is opening up more possibilities for measuring methane fluxes at new and existing eddy covariance installations.

In a growing number of applications, greenhouse gas flux measurements are making an impact. Contact LI-COR to learn more about flux networks, soil gas flux systems, and eddy covariance systems.

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