Development of a Wireless Sensor Network for Passive in situ Measurement of Soil CO2 Gas Emissions in the Agriculture Landscape

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Abstract Quantification of soil Greenhouse Gas (GHG) emissions from agricultural fields is essential for understanding the environmental impact of intensive crop and livestock production systems. Current methods of analysis include flux calculations derived from the concentration of gases (CO2, N2O, CH4) exchanged between soil and the atmosphere. Samples of these GHG are obtained manually by *closed non-steady state non-flow through,* or “static”, chambers and analyzed *ex situ* via gas analyzers, such as Gas Chromatograph (GC), Fourier-transform infrared spectroscopy (FTIR) or Cavity Ring-Down Spectroscopy (CRDS). An *in situ* analysis approach using low cost Non-Dispersive Infrared (NDIR) sensors was developed as an alternative to the current sampling and analysis method. The Wireless Sensor Network (WSN) structure of the system allows for spatial and temporal analysis of large farming areas, which was limited in the manual sampling method. CO2 fluxes from agricultural soils under various conditions are quantified using the NDIR WSN and compared with the other gas analysis methods including GC, FTIR and CRDS. The NDIR WSN is proposed as a practical tool for farmers to have access to real time GHG emission measurements.

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Introduction

The acquisition of various data from soil, crop and environmental systems is useful for shaping farming practices. Measured Greenhouse Gas (GHG) emissions, such as carbon dioxide, nitrous oxide, and methane from agricultural fields provides one such dataset that is essential for understanding the environmental impacts of intensive crop and livestock production systems. However, current sampling and measurement techniques used to obtain these datasets are labor intensive, tedious and constrain our ability to achieve the spatiotemporal scale required to describe the variability in large farm production areas, which may span hectares.

This system was developed to address the issues of practicality in data collection by proposing a cost effective Wireless Sensor Network (WSN) structure for *in situ* soil gas emission measurement using low-cost Non-Dispersive Infrared (NDIR) sensors. The WSN described in this paper is an alternative to the “non-steady-state non-flow-through”, or “static”, chamber sampling technique and *ex situ* analysis methods, such as gas chromatography (GC), that is currently used to perform GHG flux analysis. Such a WSN system allows for real time measurement of physical soil conditions and provides both spatial and temporal insight into the conditions affecting GHG fluxes in soils (Mat Su, 2014).

Closed Non-Steady State Chamber and Ex-Situ Analysis

As part of McGill’s collaboration with the Agri-food Canada Agriculture Greenhouse Gas Program (AGGP), in which the effects of irrigation and drainage practices on soil gas emissions were studied (Mat Su, 2016; Lloyd, 2016), non-steady state non-flow through chambers (“Static” Chamber) were used to measure GHG flux. Standard sampling procedure involves the manual collection of 5 gas samples spaced equally over the course of an hour from a sampling valve for each chamber. Samples are extracted using a 20mL syringe and transferred into a 12mL vacuumed exetainer. The samples are then analyzed with a Gas Chromatograph for CO2, N2O and CH4 concentrations (Lloyd, 2016).

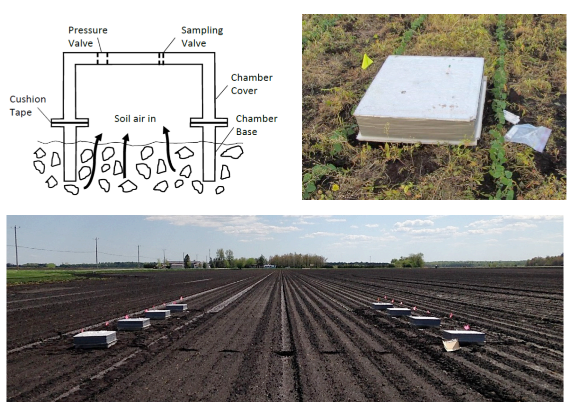

Figure 1. Working Principal of a standard Closed Static Chamber (top left) (Florian Reumont, 2016), Non-steady state chamber (top right) (Mat Su, 2016), GHG sampling layout in field (bottom) (Lloyd, 2014)

Due to the limitations in spatiotemporal measurements using manual sampling methods with the static chambers, the NDIR based WSN was developed as an alternative to close this gap. GC measurements from the static chambers are used as a comparison to the measurements obtained from the NDIR sensors (Reumont, 2016).

Low-cost Non-Dispersive Infrared Sensor based Chambers

The NDIR based chambers are portable, hand-held sensor systems electronically driven by an Arduino Microcontroller. The primary components of the chambers include the K30 NDIR CO2 Sensor (SenseAir), the main chamber headspace, and the soil blade. Pressure (BMP280), temperature and humidity (DHT11) sensors are also included for the auxiliary measurement of environmental conditions.

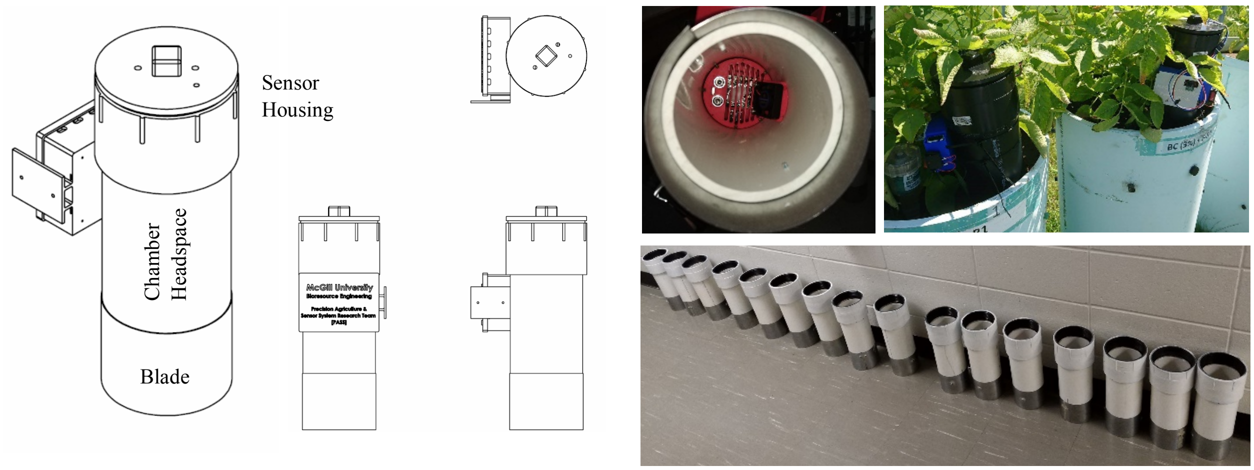

Figure 2. WSN chamber design (left), NDIR chambers(right) (Debbagh, 2018)

These chambers retain the working principle of passive GHG accumulation within the chamber headspace that is used in the closed static chambers to perform GHG flux calculations. The ultrasonic sensors found within the chambers perform height measurements for variable depth volume calculations of the headspace, which is also used for flux calculations.

Network Structure

As previously mentioned, the communication structure of the chambers operates as a Wireless Sensor Network. Each chamber (Node) is equipped with a radio transceiver module (LoRa) operating in the 915 MHz band for long distance transmission of >10 km in rural areas. The network can be classified as a Low Power Wide Area Network (LPWAN) and uses a Raspberry Pi based gateway to transfer data to a server via TCP/IP or into local memory.

Conclusion

Current soil gas sampling practices may provide a possible source of influence in the high spatial variability observed in CO2 flux measurements obtained by closed static chambers. An NDIR WSN based approach is a potential alternative that can mitigate the effects of impractical sampling procedures and provide insight into the conditions affecting soil emissions. This network also provides farmers with cheaper access to farm monitoring technology and data.

References

Mat Su, A. S., Adamchuk, V. I., Whalen, J. K., Benslim, H., & Tam, K. (2014). Predicting changes in greenhouse gas emissions in muck soil using physical observations. In 2014 Montreal, Quebec Canada July 13–July 16, 2014 (p. 1). American Society of Agricultural and Biological Engineers.

Mat Su, A. 2016. Application of Proximal Soil Sensing for Environmental Characterization of Agricultural Land. in: Bioresource Engineering, Vol. MS Thesis, McGill University. Montreal, Quebec, pp. 130.

Reumont, F. (2016). Development of a Portable Instrumentation System for In Situ Assessment of Soil Respiration (Doctoral dissertation, McGill University).

Lloyd, K. (2016). Greenhouse Gas Emissions from Onion Fields Cultivated on Organic Soils Under Sprinkler Irrigation in Quebec (Doctoral dissertation, McGill University Libraries).