CROSS-VALIDATION OF A NOVEL LOW-COST NITROUS OXIDE AND CARBON DIOXIDE SENSING SYSTEM USING A PICARRO GAS ANALYZER

ABSTRACT

We introduce a novel, cost-effective sensor system designed to accurately measure nitrous oxide (N2O) and carbon dioxide (CO2) concentrations and, by extension, the fluxes, and then validate the performance against the Picarro G2508 Gas Analyzer, a standard in precision atmospheric greenhouse gas measurement. The affordability of this new sensor system could significantly enhance its accessibility and deployment, particularly in diverse agricultural settings, thereby providing a more detailed understanding of soil-atmosphere gas flux dynamics critical for both optimizing farming practices and improving climate change models.

INTRODUCTION

Global Warming Potential of N2O and Importance of Measurement

Nitrous oxide (N2O) is a potent greenhouse gas with a global warming potential approximately 273 times that of carbon dioxide (CO2) under the IPCC 6th Assessment Report. Predominantly produced from agricultural activities, such as field management and fertilization, N2O emissions significantly contribute to the greenhouse gas footprint of farming operations. Accurate measurement of these emissions is crucial for developing strategies that mitigate environmental impact while maintaining agricultural productivity.

Additionally, Carbon Dioxide is a greenhouse gas emitted and absorbed by soil during agricultural activities. Accurate measurement of emissions and sequestration is crucial for understanding and developing climate-smart agricultural practices that store atmospheric carbon in healthy soil.

CURRENT CHALLENGES IN GAS MEASUREMENT

Currently, high-precision instruments like the Picarro G2508 Gas Analyzer are used to measure atmospheric gasses. While accurate, these systems are cost-prohibitive and logistically complex, limiting their widespread use in field conditions, particularly across developing regions or diverse farming ecosystems.

POTENTIAL OF LOW-COST SENSORS

The development of low-cost sensors capable of comparable accuracy presents an opportunity to democratize this important measurement capability, making it feasible to implement on a much larger scale and in more varied environments. This study focuses on the characterization and validation of such sensors against established laboratory-grade equipment.

METHODOLOGY

LABORATORY CALIBRATION

Experimental Setup

The experimental setup includes the Agrology Arbiter Soil Chamber, which is equipped with an integrated sensor array and server-side machine-learning algorithms to process the measurements. The chamber establishes a controlled measurement volume through a water seal at its base. Calibration gasses with known concentrations of N2O and CO2 are introduced into this volume.

Image 1: Laboratory calibration experimental setup

CALIBRATION PROCESS

1. The Picarro G2508 Gas Analyzer is connected via plumbing to the chamber to sample gas from within the measurement volume.
2. Different mixes of N2O and CO2 are used to calibrate the sensors, starting with concentrations as low as 10 PPB N2O and 500 PPM CO2.
3. The setup records data from both the Agrology sensor array and the Picarro Analyzer, comparing these to assess accuracy and establish calibration curves.

Images 2/3: In-field testing setup

FIELD TESTING

Set Up Installation

Field testing was conducted in a manure-flood irrigated corn silage field known for high N2O emissions. The soil chamber was installed at the site, with the Picarro Analyzer connected via a gas sampling circulation loop to allow placement outside the field's hazardous zone.

Data Collection

Data collection spanned 8 weeks, during which gas concentrations were continuously recorded by both the Agrology system and the Picarro Analyzer to validate the laboratory calibrations under field conditions.

RESULTS

Performance Metrics

The Agrology system achieved an R^2 value of 0.832 for CO_2 and 0.862 for N_2O, indicating strong predictive accuracy compared to the Picarro system.

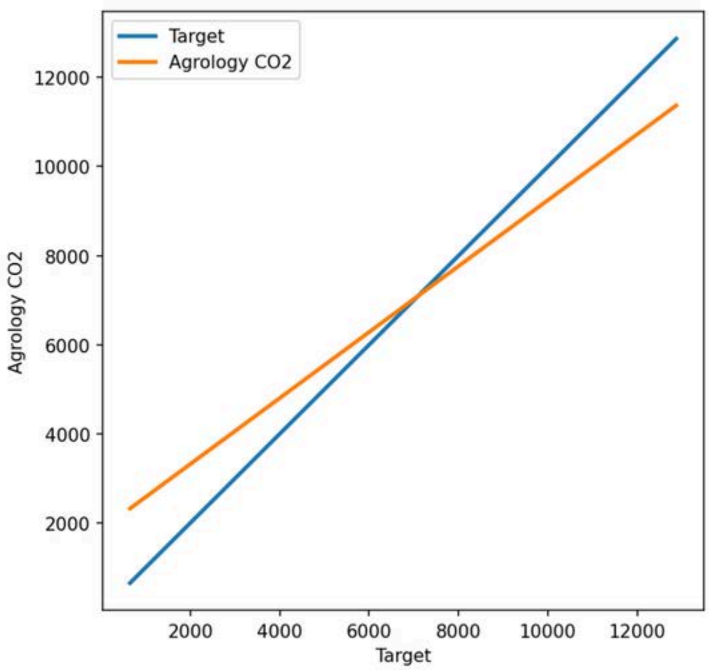

Figure 1: Linearity comparison of Agrology and Picarro (Target) CO2 data in PPM

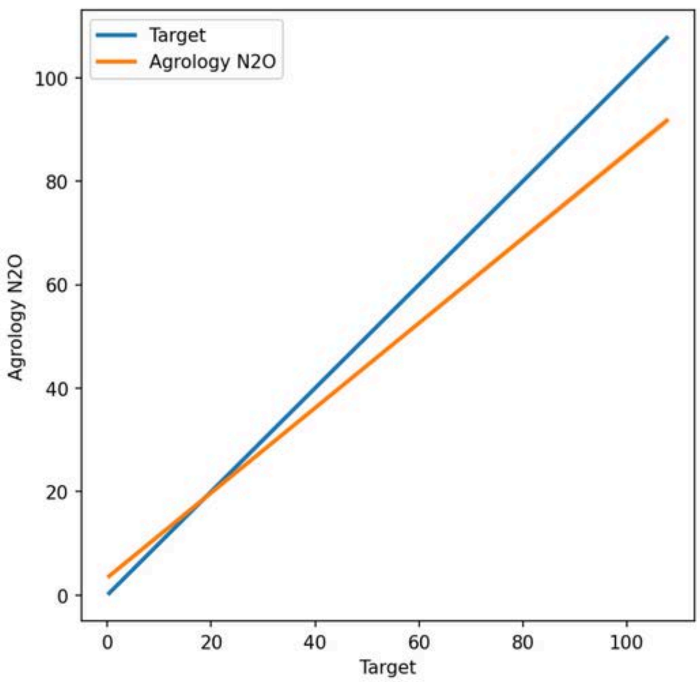

Figure 2: Linearity comparison of Agrology and Picarro (Target) N2O data in PPM

Mean Absolute Errors (MAE) were 716.8 PPM for CO_2 and 4.8 PPM for N_2O, within acceptable ranges for field applications.

RESULTS

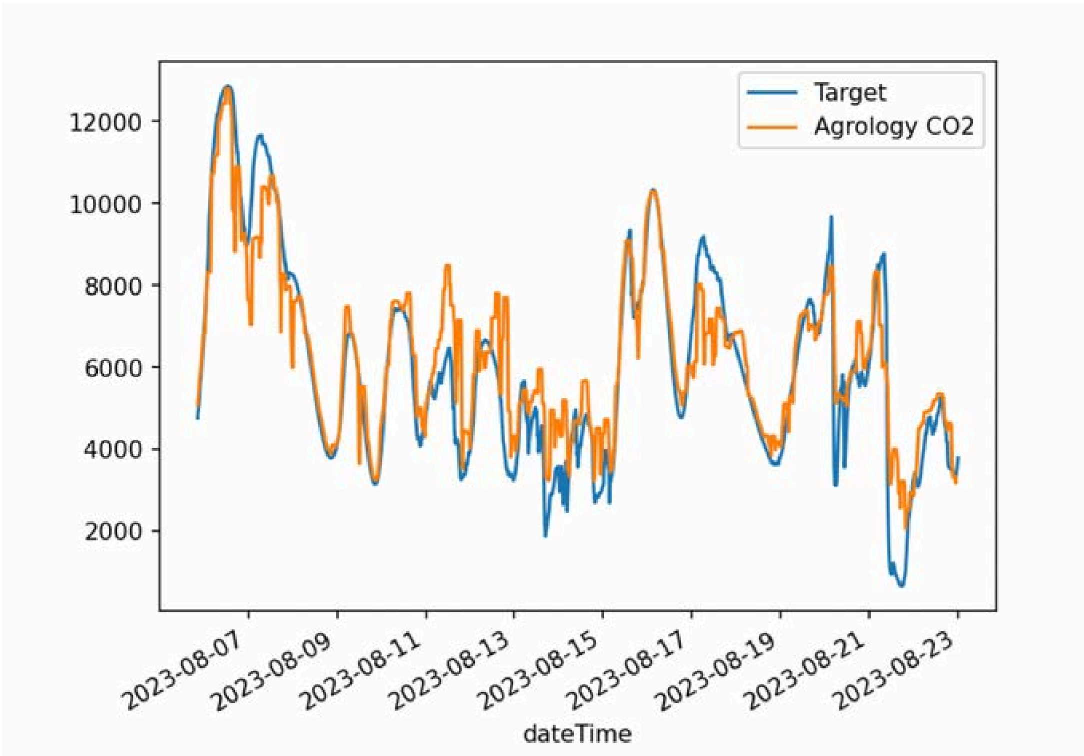

Figure 3: Time series measurement comparison of Agrology and Picarro (Target) CO2 data in PPM

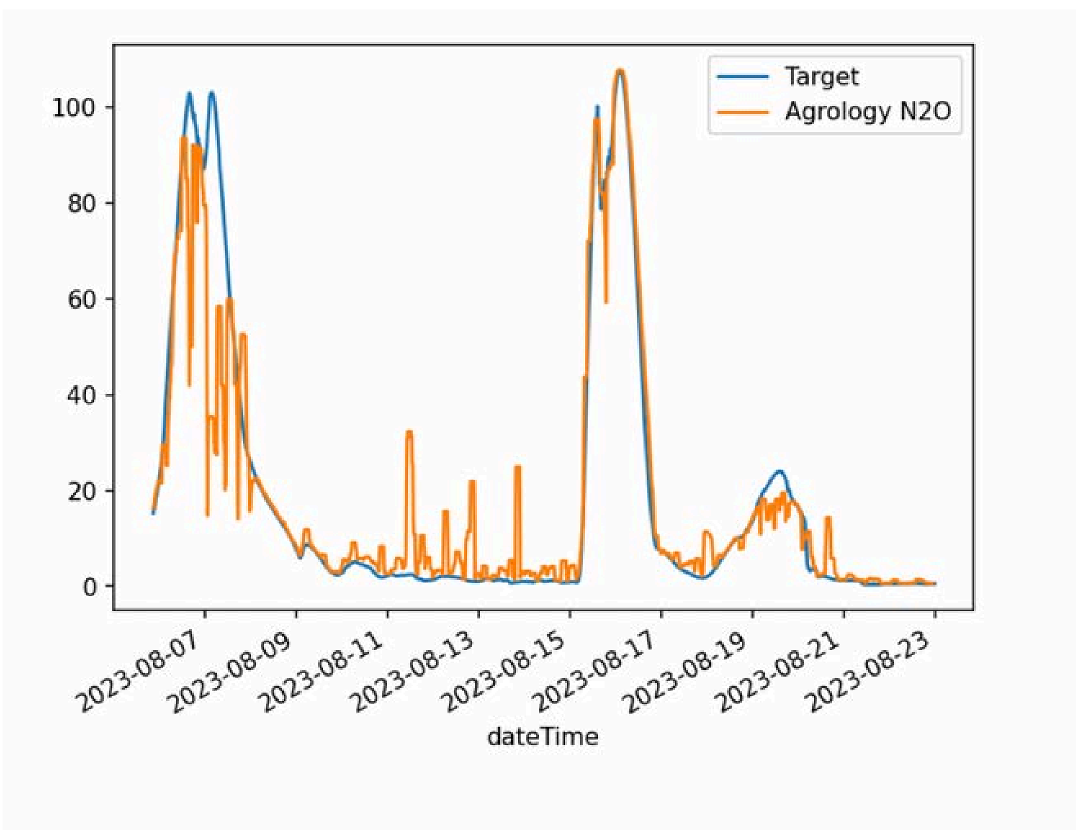

Figure 4: Time series measurement comparison of Agrology and Picarro (Target) N2O data in PPM

RESULTS

Comparative Analysis

The analysis shows that while there is some error attributed to system response times (hysteresis), primarily due to the long gas sampling loop, the overall accuracy of the Agrology system is robust, suggesting it as a viable alternative to more expensive equipment for many applications.

DISCUSSION

Implications of Findings

The introduction of the Agrology Arbiter Chamber system represents a significant advancement in environmental monitoring technology. It provides a cost-effective solution without substantially sacrificing accuracy. The system's scalability and ease of deployment promise enhanced monitoring of greenhouse gas emissions across various landscapes, potentially leading to more precise agricultural models and improved strategies for emission reduction.

Future Directions

Continued refinement of the machine learning algorithms and expansion of the sensor capabilities to include other relevant gasses like methane are planned. These enhancements will further the system's applicability and precision in broader environmental research and monitoring efforts.

Conclusion

This study confirms the effectiveness of the Agrology Arbiter Chamber system as a reliable, accurate, and cost-efficient method for measuring N_2O and CO_2 fluxes in agricultural settings. By enabling broader deployment and denser sensor networks, this technology can significantly improve our understanding and management of greenhouse gas emissions from agriculture, with positive implications for both farm sustainability and climate change mitigation.