Cumulative Evaporation from Surface-Applied Manure Using a Closed Dynamic Chamber Technique

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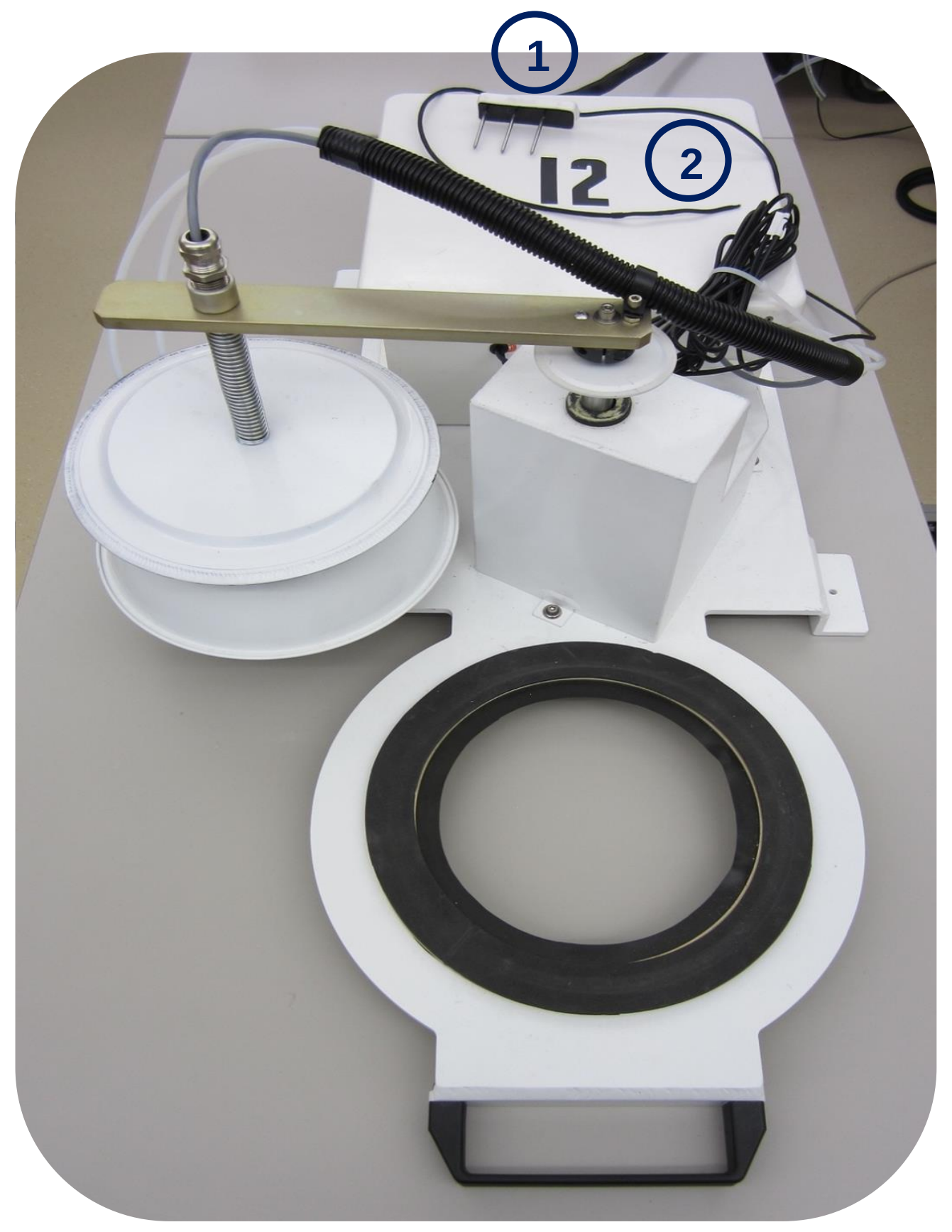
ABSTRACT

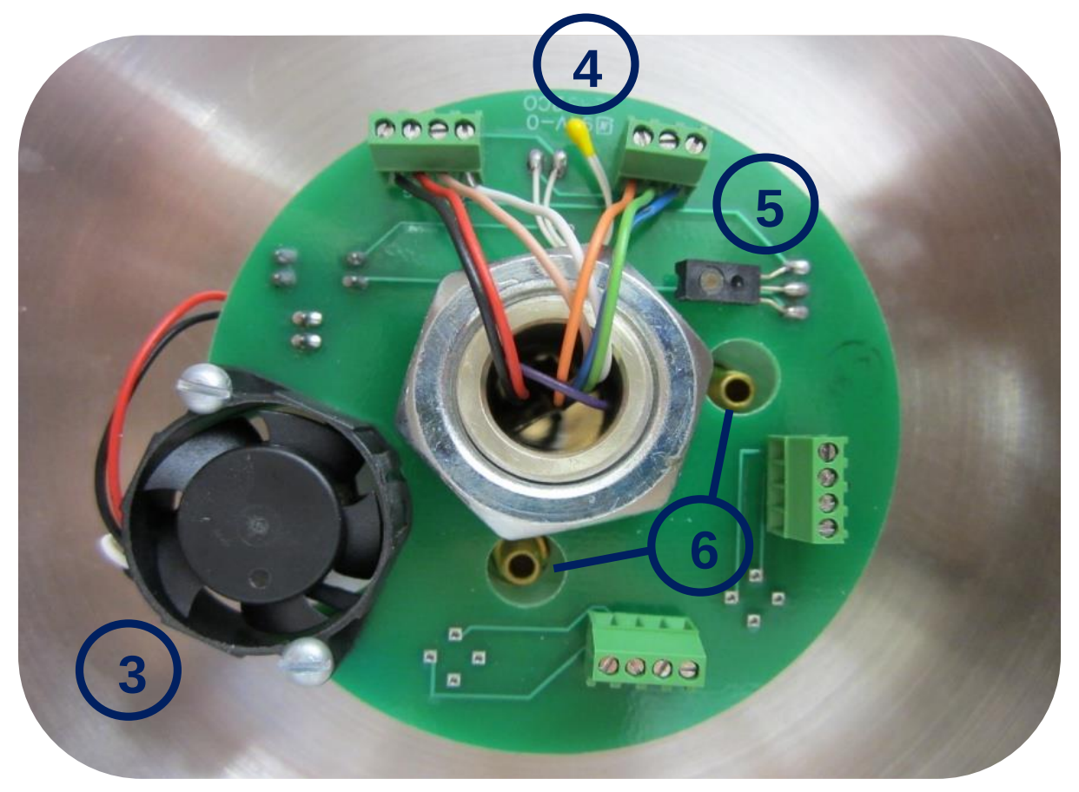
Manure surface application is considered one of the most effective best management practices in reducing the nutrient impacts of livestock operations on surface and ground waters. Manure and its use as fertilizer can also contribute to gaseous and particulate emissions, significantly degrading air quality to the detriment of human health and the environment. The objective of our study was to estimate evaporative water loss to correlate with CO_2, NH_4 and NH_3 emissions from surface-applied manure. We established manure surface application plots at the USU Greenville Research Farm during the summer of 2013 to quantify gaseous emissions from four types of manure source (i.e. dairy manure, beef manure, dairy compost, and beef compost) and to investigate the temporal and spatial characteristics of the emissions. The temperature and relative humidity (RH) were monitored using a thermistor and relative humidity sensor mounted inside each of 12-surface chambers. Soil/manure moisture contents were determined using dielectric sensors. Results from our study enhance development and implementation of surface chamber-based assessment of gas loss by demonstrating correlation between gas emissions, water vapor mass loss and surface moisture measurements.

CHAMBER COMPONENTS

The system is based on the closed dynamic chamber principle and includes state-of-the-art moisture sensors, thermistors, and relative humidity (RH) sensors to monitor and examine the primary physical factors directly influencing gas production and transport mechanisms.



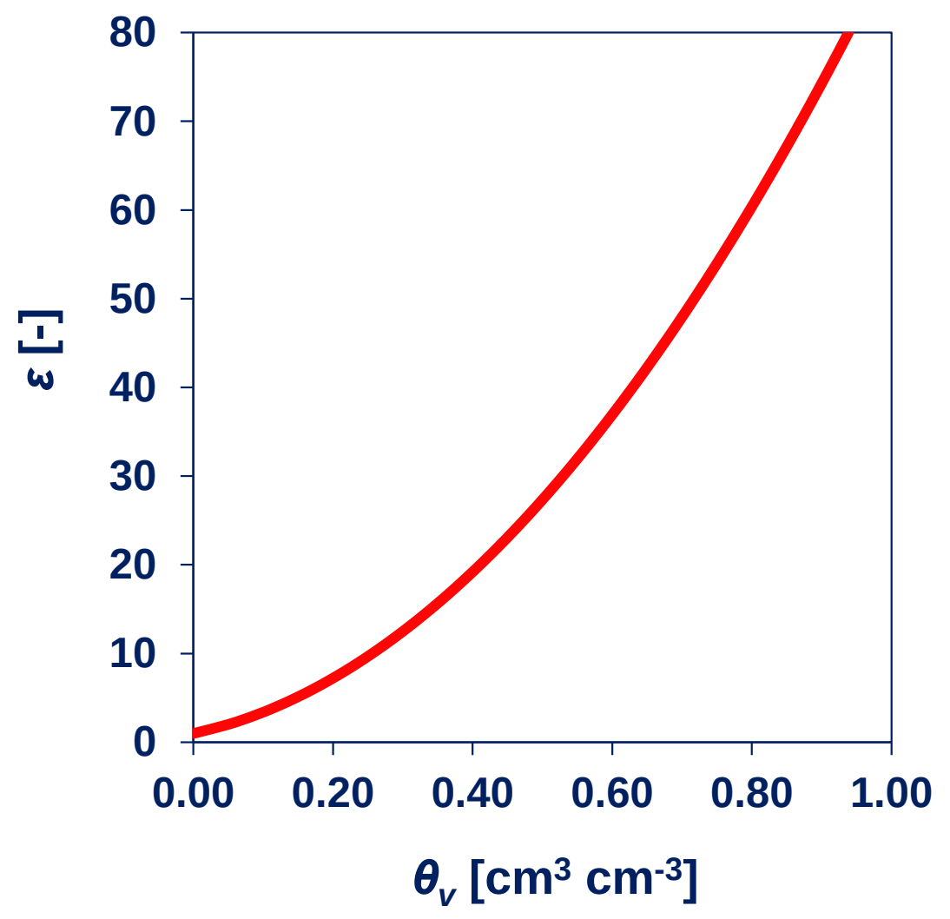
1. GS3 sensor (Decagon Devices, Inc.) measuring dielectric permittivity (moisture content), electrical conductivity (EC), and temperature
2. External 10K ohm thermistor (Apogee Instruments, Inc.)
3. 12 VDC fan (model DF122510BL, top motor)
4. Internal 10K ohm thermistor (Apogee Instruments, Inc.)
5. Relative humidity (RH) sensor (model HIH-4021-001, Honeywell Sensing and Control)
6. Bulkhead fittings for gas sampling inlet/outlet



Each custom-made chamber is equipped with an external GS3 moisture sensor and thermistor (above left). The surface chamber is designed to house a circuit board with a fan and sensors to measure temperature and relative humidity inside the chamber (above right). The chamber volume and exposed soil area are 4,076 cm^3 and 317.8 cm^2 (49.3 in^2), respectively.

THEORETICAL CONSIDERATIONS

A. Determination of Soil/Manure Moisture Content



Volumetric water content (θ_v) of soil/manure was determined from the dielectric permittivity (ε) outputted from the GS3 sensor. A generic calibration expression used in converting ε to θ_v is shown below and plotted on the left.

$$\theta_V\ [\mathrm{cm^3\ cm^{-3}}] = 0.118 \cdot \sqrt{\varepsilon_a} - 0.117$$

The surface evaporation process was estimated to occur in the top 5 cm (± 2 inches) of soil.

B. Monitoring RH with Closed Chamber Technique

The absolute humidity (*AH*) in units of g m^{-3} was calculated from the relative humidity (RH) measured inside the closed chamber:

$$AH = \frac{C \cdot P_w}{(T + 273.15)}$$, where

C **= Constant 2.16679 gK J^{-1}, *T* = Temperature in degree Celsius, and P_w = Vapor Pressure in Pa, determined from:**

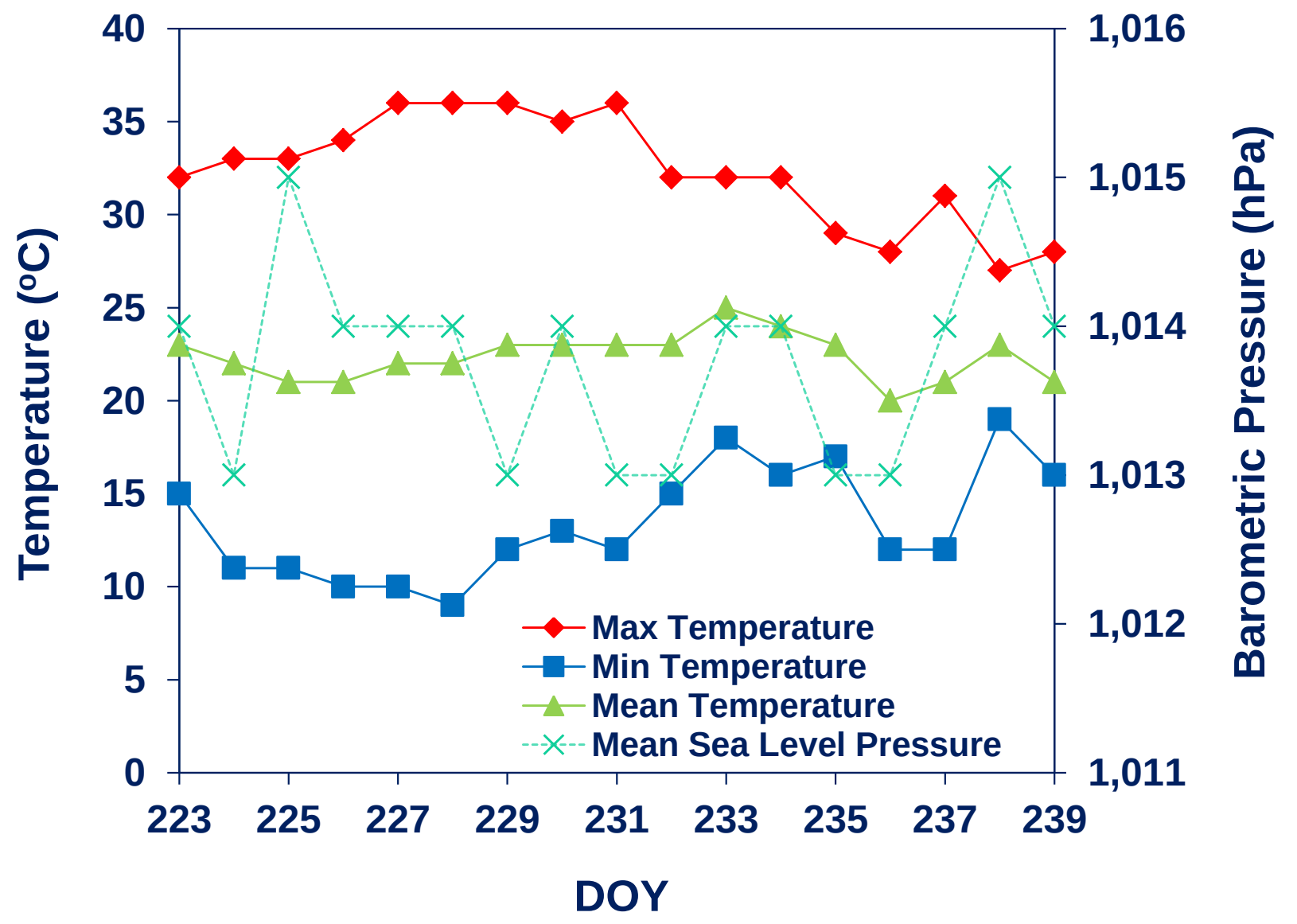
$$P_w = A \cdot 10^{\left(\frac{m \cdot T}{T + T_n}\right)} \cdot \frac{RH}{100}$$, where

A, m, and T_n are constants listed in the table below (for temperatures in range of -20 to 50 °C).

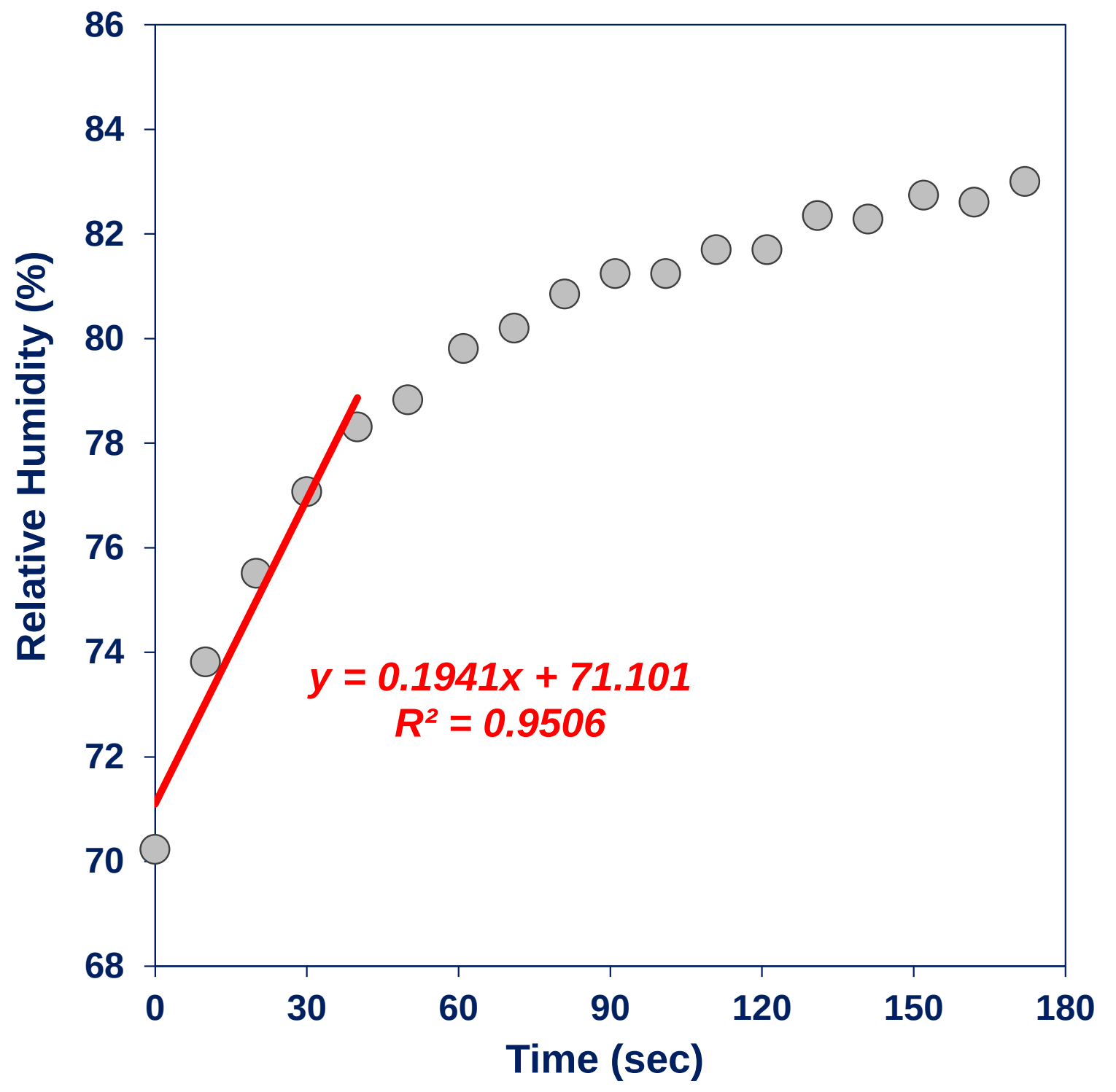
A	m	T_n	Max. error
6.116441	7.591386	240.7263	0.083%

EXPERIMENTAL SETUP

Manure surface application plots were set up at Greenville Research Farm in North Logan, UT (below left) during August 2013 to quantify gaseous emissions from four types of manure source (i.e. dairy manure, beef manure, dairy compost, and beef compost). The soil/manure moisture content sensors were inserted into the surface to a depth of 2 inches. In addition to gas emissions, primary meteorological factors affecting evaporation, including ambient temperatures were monitored (below right).



RESULTS AND DISCUSSION



An example of regression of chamber relative humidity versus time is shown on the left. Approximately after 40 seconds, the relative humidity gradient under the measuring chamber decreases with time as the sampled air accumulates. This is most likely affected by change in temperature inside the chamber after closing, particularly during the day time. To overcome potential underestimation of evaporation rate, we assumed a constant evaporation rate and used a linear model in a short period (±40 seconds) to determine the increasing rate of the relative humidity.

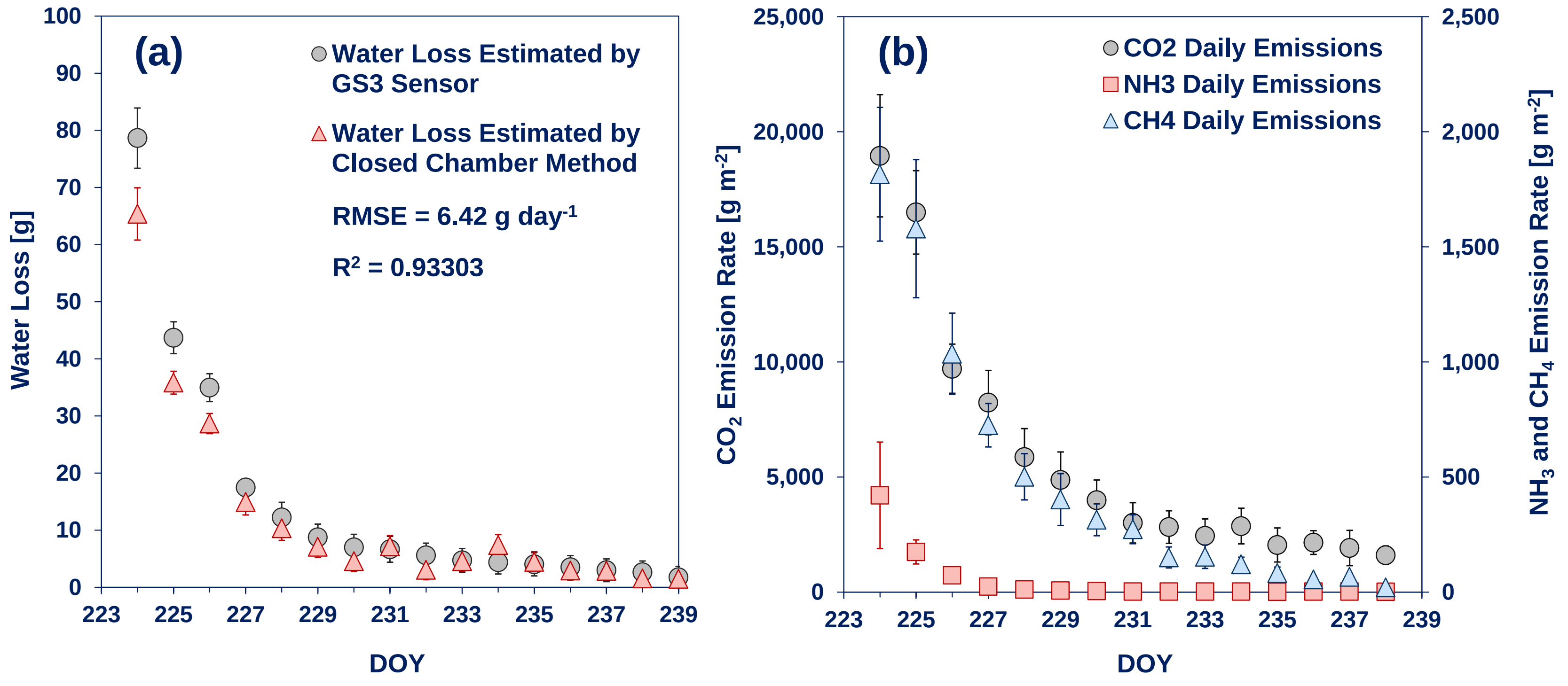


Figure above (a) demonstrates a comparison of daily water loss due to the surface evaporation between using the soil/manure moisture sensor and closed chamber technique during the course of experiment. The closed chamber method has a tendency to underestimate during high evaporation rate. Figure (b) illustrates the 15-day emission patterns of CO_2 (left axis), NH_3 and CH_4 (right axis) sugesting strong potential to estimate greenhouse gas emissions using water loss measurements with further correlation analysis.

ACKNOWLEDGEMENTS

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