Predicting Greenhouse Gas Emissions from Beef Cattle Feedyard Manure

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INTRODUCTION

The Texas Panhandle is the largest beef feeding area in the US, producing approximately 20% to 30% of finished beef. Beef cattle feedyards are sources of greenhouse gases (GHG), most notably enteric methane (CH_4) and manure-derived nitrous oxide (N_2O) and CH_4. However, little information exists on the magnitude of feedyard GHG emissions or the factors that influence their production. Valid prediction methods are needed to inventory feedyard GHG and assess the impact of beef production on the environment. Most biochemical process-based models to predict GHG rely on information derived from studies on soil, which may, or may not, be valid for manure in open lot systems. The limited study on manure-derived feedyard GHG indicates that fluxes of both N_2O and CH_4 are highly variable in space and time. Improved understanding of factors related to manure-derived GHG could help refine process-based models and produce useful empirical models for predicting the environmental footprint of feedyard beef. In turn, this could lead to more accurate inventory calculation techniques for regulatory agencies.

OBJECTIVES:

- ***Determine factors related to production and volatilization of N_2O and CH_4 from manure in beef cattle feedyard pens***
- ***Develop empirical models to predict GHG emissions based on manure physicochemical properties***

MATERIALS AND METHODS

- GHG flux data and manure samples were collected during 8 four-day non-flow-through, non-steady-state (NFT-NSS) chamber studies conducted in 2012 and 2013 on two Texas Panhandle feedyards (Feedyard A and Feedyard C; ***Fig. 1***). Each pen contained 10 NFT-NSS chamber bases inserted into pack manure (***Fig. 2a and b***). Chambers were located in specific areas (e.g., near feedbunk and water trough areas, back of pen, middle of pen, etc.) and contained sensors to record manure temperature. After fitting the base with a chamber cap, headspace was sampled with a disposable syringe at 0, 10, and 30 min. Concentrations of N_2O and CH_4 were quantified with gas chromatography (***Fig. 3***). See the presentation of Casey et al. (Mon. 1:00, Paper: 96-1) for specific details

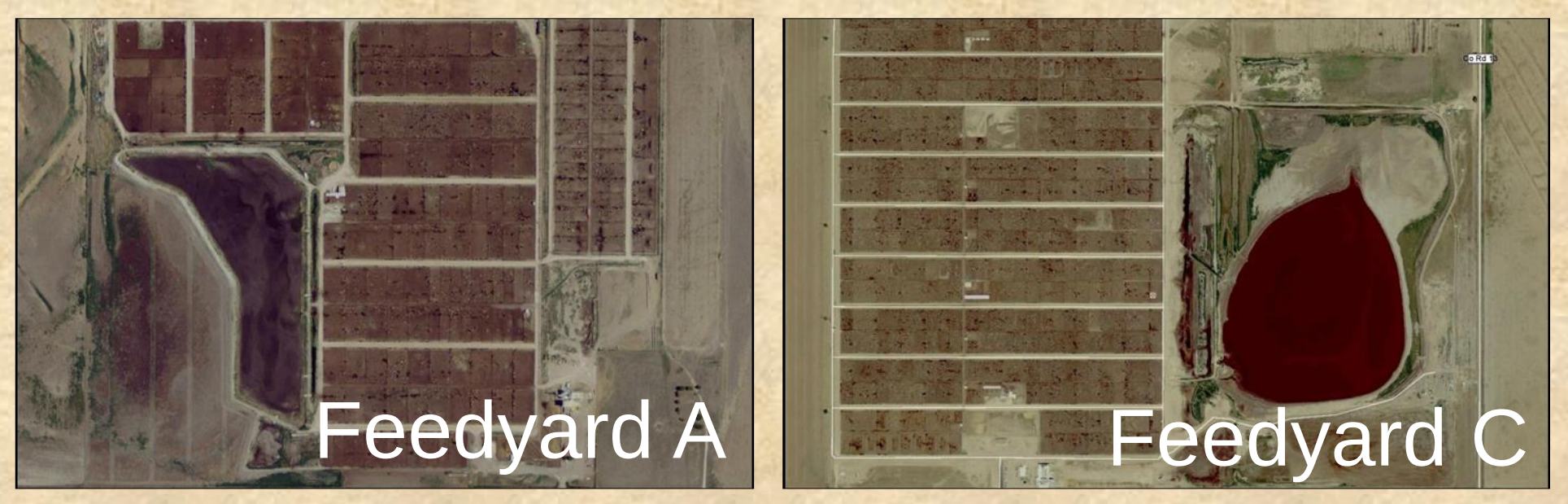


Figure 1. Aerial views of Feedyard-A (left; 22,000 head capacity) and Feedyard-C (right; 55,000 head capacity).

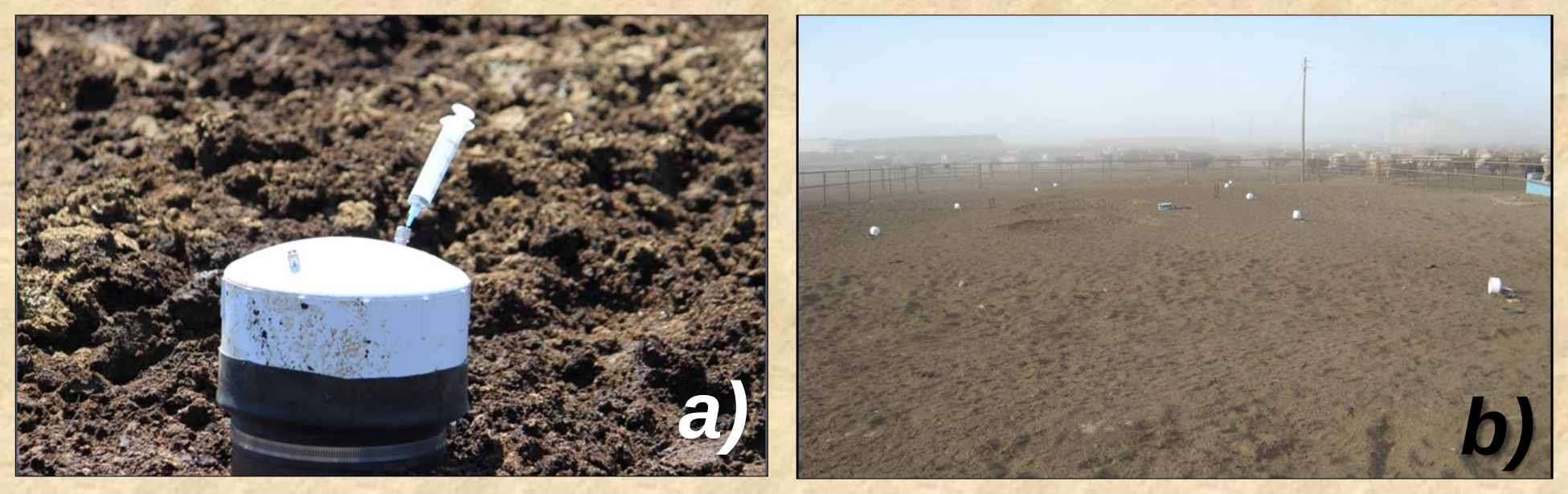


Figure 2. a) NFT-NSS chamber with top installed, and ***b)*** two rows of five NFT-NSS chambers installed in a pen at Feedyard-C.

- Physicochemical properties of the dense pack fraction of pen manure are presented in ***Table 1***. There were a total of 79 GHG measurements and manure samples. Water-extractable manure organic matter [WEOM; 1:100 (wt:vol)] was analyzed for dissolved organic carbon (DOC), total dissolved carbon (DC), and total dissolved nitrogen (DN).
- Ultraviolet-visible (UV-vis) spectral characteristics of WEOM were evaluated between the wavelengths of 200 and 700 nm. Absorbance at 254 nm (OD254), and ratios of E2/E6 (proportion of humified to non-humified material) and E4/E6 (degree of humification, molecular weight, aromaticity) were calculated based on absorbances at 254, 280, 472, and 664 nm.
- Mixed modeling (Proc MIXED) was used to develop empirical equations to predict manure-derived N_2O emissions. Study was set as a random variable. Models were evaluated by regression and measures of difference (Willmott et al., 1982) and compared to two randomly chosen subsets (n = 20) of the original dataset.

Reference: Willmott, C.J. 1982. Bull. Am. Met. Soc. 63:1309-1313.

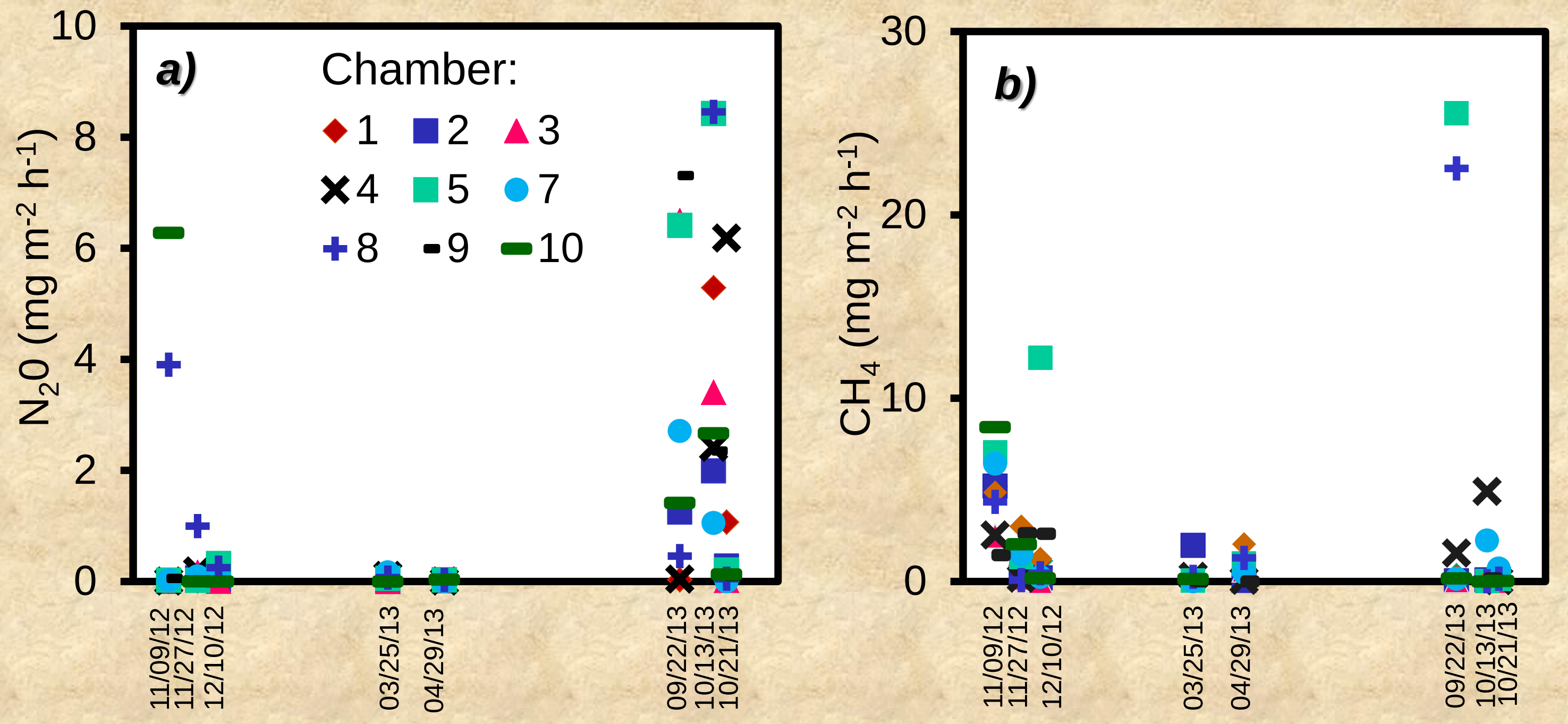


Figure 3. Emissions of ***(a)*** nitrous oxide (N_2O) and ***(b)*** methane (CH_4) from manure in two commercial Texas feedyards. Gas fluxes were determined using NFT-NSS chambers (10 chambers per sampling date, designated Chambers 1-10) and gas chromatography. *Emissions of both GHG were highly variable due to environmental conditions and locations of chambers within pens. Average fluxes were 1.1 ± 2.2 and 1.9 ± 4.3 mg m^{-2} h^{-1} for N_2O and CH_4, respectively.*

Table 1. Summary statistics. Correlation coefficients (R; n = 79) were used to identify primary variables related to GHG emissions. Asterisks indicate significance at: $P \leq$ 0.05 (*), 0.01 (**), 0.0001 (***). NS, not significant. *Most of the variables investigated were related to measured N_2O fluxes (P < 0.01), and nitrate concentration had the highest R value. In contrast, few significant relationships were identified for CH_4 flux: only OD254 nm, which indicates organic matter complexity, was significant (P < 0.001).*

Variable	Mean ± Standard Deviation	Range	R CH_4	R N_2O
Nitrous oxide (mg m^{-2} h^{-1})	1.12 ± 2.17	0 - 8.46	NS	--
Methane (mg m^{-2} h^{-1})	1.91 ± 4.27	0 - 25.5	--	NS
Moisture (%)	28.6 ± 8.9	9.1 - 48.7	0.219	**0.319****
Surface temperature (°C)	20.1 ± 11.6	1.8 - 39.8	0.164	**0.314****
Organic matter (% DM)	69.9 ± 7.4	44.4 - 83.3	0.241	**-0.327****
Ammonia/ammonium-N (g kg^{-1})	3.05 ± 2.31	0.35 - 10.9	NS	**-0.396*****
Nitrate/nitrite-N (mg kg^{-1})	6.87 ± 16.3	0 - 106	NS	**0.580*****
Dissolved organic C (mg g^{-1})	28.4 ± 5.2	18.3 - 45.2	NS	**-0.413*****
Dissolved total C (mg g^{-1})	31.4 ± 5.9	20.6 - 50.1	NS	**-0.419*****
Dissolved N (mg g^{-1})	9.52 ± 3.60	2.66 - 18.2	NS	**-0.466*****
OD254 nm	0.758 ± 0.139	0.538 - 1.18	**0.408*****	NS
E2/E6	66.4 ± 20.6	21.2 - 127	NS	**-0.324****
E4/E6	5.00 ± 0.98	2.45 - 8.32	NS	-0.266*

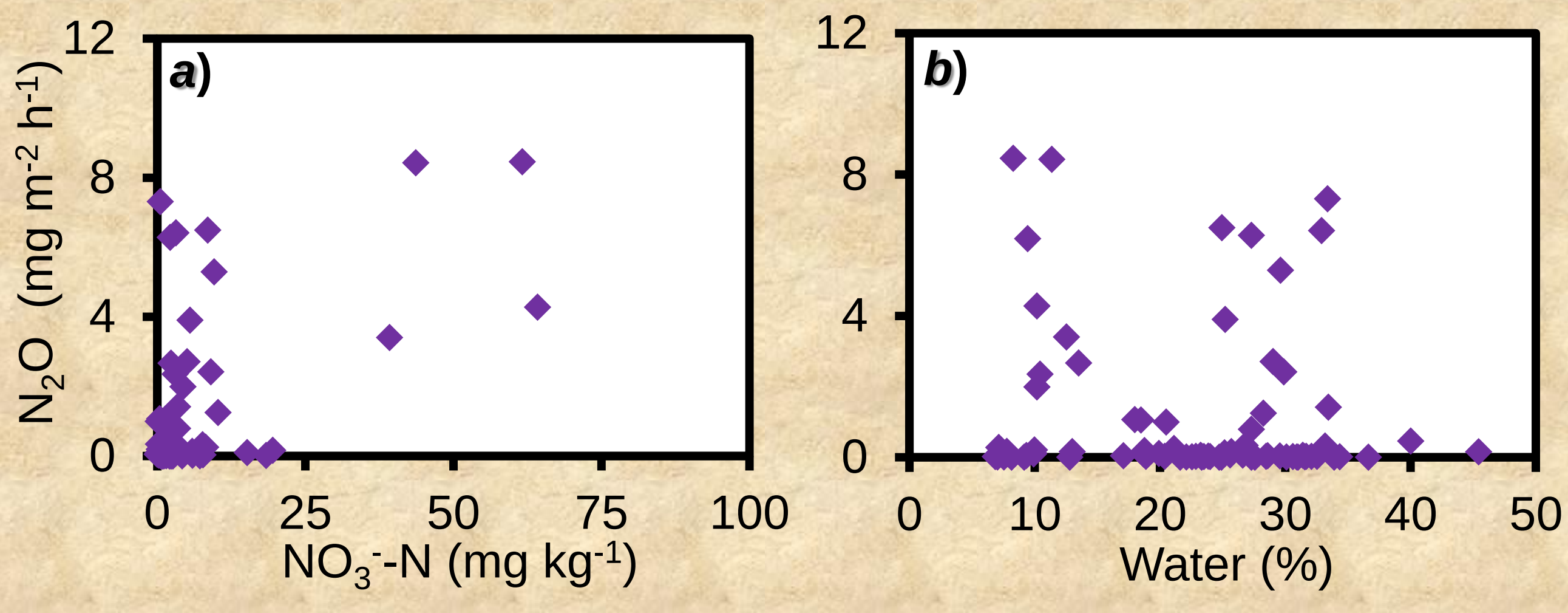


Figure 4. Relationships between manure ***a***) NO_3^--N and ***b***) water content (% w/w) and N_2O fluxes. *N_2O flux tended to increase with manure NO_3^- and were highest at ~ 10% and 30% water content.*

Table 2. Statistical evaluation of model performance with measures of difference (MBE, Mean bias error; RMSE, Root mean square error; MAE, mean absolute error). *Model evaluation indicated 70% to 86% agreement of predictions with measurements with very low bias estimates. Measures of error decreased and model agreement increased when UV-vis spectral characteristics were used to model N_2O emission.*

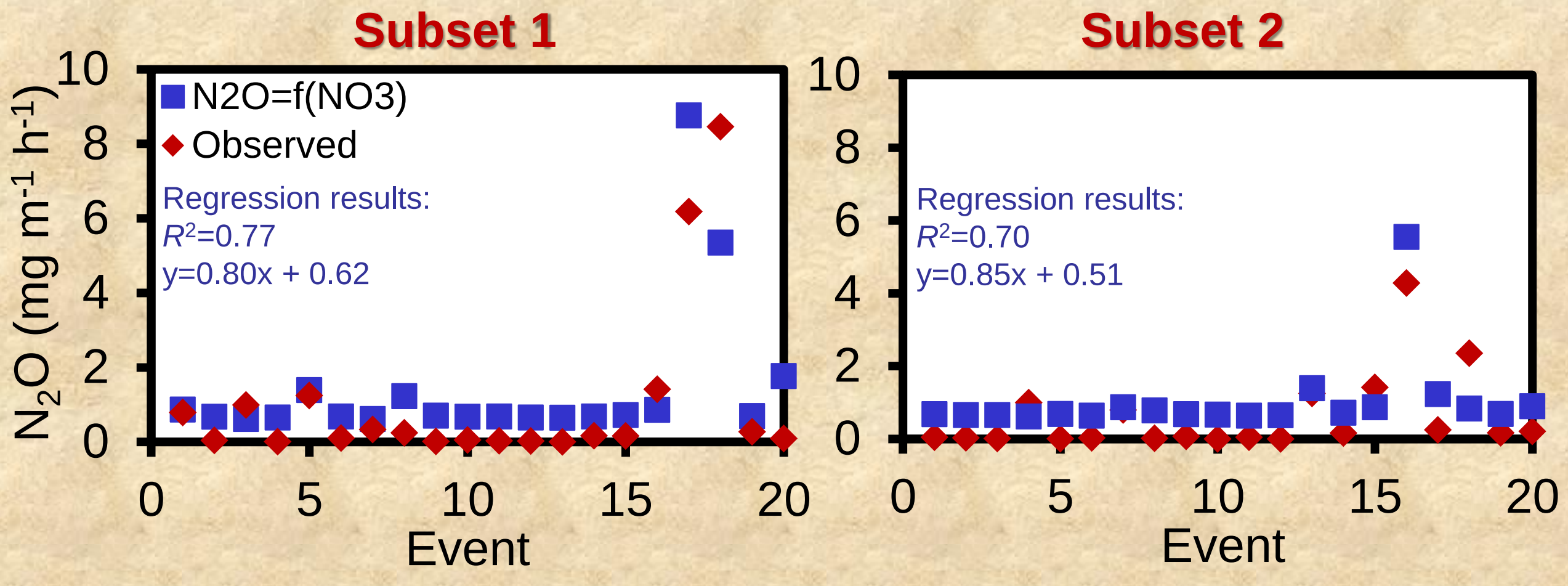
Measure of difference	**Model 1:** ***f(NO3)***	**Model 2:** ***f(NO3, W, T, DC)***	**Model 3:** ***f(NO3, W, T, DC, OD254, E2/E4, E4/E6)***
MBE (mg m^{-1} h^{-1})	-0.001	0.014	0.0002
RMSE (mg m^{-1} h^{-1})	1.78	1.63	1.39
MAE (mg m^{-1} h^{-1})	1.19	1.10	0.97
Index of Agreement (%)	69.8	76.3	85.6

RESULTS

A number of empirical models were developed to predict feedyard manure-derived N_2O emissions that were based on manure properties. Models were evaluated against two subsets of the original dataset (Subset 1 and Subset 2) and are as follows (***Fig. 5***):

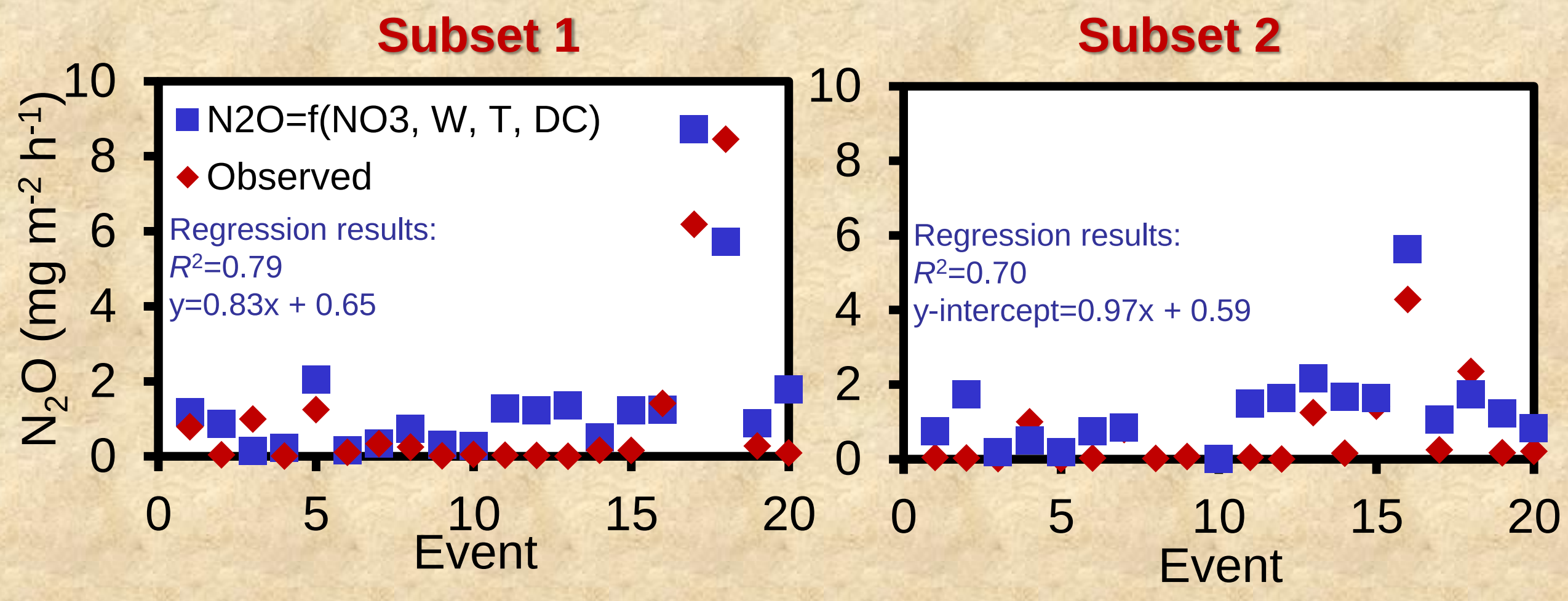
- ***Model 1:*** Predicted N_2O flux (*N2O*, mg m^{-2} h^{-1}) as a function of manure NO_3^--N concentration (*NO3*, mg kg^{-1})

$N2O$ = 0.599 + $NO3$(0.077)



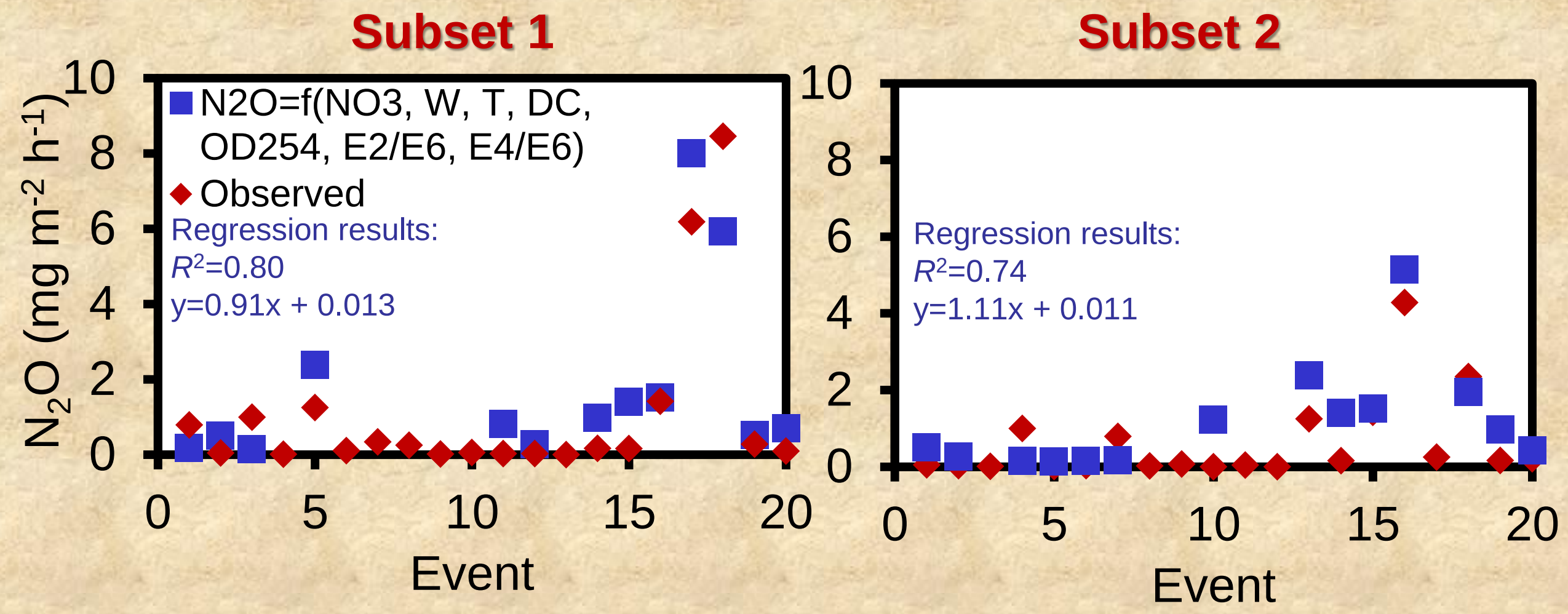
- ***Model 2:*** Predicted N_2O flux as a function of *NO3*, water content (*W*, proportion), temperature (*T*, °C), and water-extractable C content (*DC*, mg g^{-1})

$N2O$ = 2.77 + $NO3$(0.066) + W(0.5988) + T(0.032) + DC(-0.092)



- ***Model 3:*** Predicted N_2O flux as a function of *NO3*, *W*, *T*, *DC*, and UV-vis spectral characteristics (*OD254*, *E2/E6*, *E4/E6*)

$N2O$ = 9.08 + $NO3$(0.060) + W(5.46) + T(0.029) + DC(-0.377) + $E2/E6$(-3.55) + $E4/E6$(0.171) + $OD254$(10.26)



CONCLUSIONS

- Emissions of both GHG were highly variable due to environmental conditions and locations of chambers within pens. Average fluxes were 1.1 ± 2.2 and 1.9 ± 4.3 mg m^{-2} h^{-1} for N_2O and CH_4, respectively *(**Fig. 3a and b**).*
- Most of the variables investigated were related to measured N_2O fluxes (P < 0.01), and nitrate concentration had the highest R value. In contrast, few significant relationships were identified for CH_4 flux: only OD254 nm, which indicates organic matter complexity, was significant (P < 0.001) *(**Table 1**).*
- N_2O flux tended to increase with manure NO_3^- *(**Fig. 4a**)* and was highest at ~ 10% and 30% water content *(**Fig. 4b**).*
- Predicted N_2O flux from empirical models developed in this study had 70% to 80% agreement with measurements, and the models adequately simulated both high and low values *(**Table 2**).*
- Inclusion of UV-vis spectral characteristics (Model 3) improved model predictions somewhat: regression analyses for the two data subsets and Model 3 predictions produced R^2 values of 0.74 to 0.80 with intercepts near O and slope near 1 *(**Fig. 5**).*
- Further work is required to evaluate these models against an independent dataset and develop equations for predicting manure-derived CH_4 emission.

ACKNOWLEDGEMENTS

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