Estimation of Ammonia Emissions from Beef Cattle Feedyards in the Southern High Plains with Process-Based Models

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INTRODUCTION

Valid estimates of ammonia (NH_3) emissions from beef cattle feedyards are needed to assess the impact of beef production on the environment, to comply with reporting requirements, and to develop reasonable regulatory policies. Production and volatilization of NH_3 are strongly influenced by environmental and management factors (***Fig. 1***), which are not captured by constant emission factors. Therefore, process-based models, which track components of interest through biochemical and geochemical reactions as functions of specific conditions (e.g. temperature, pH, precipitation and dietary protein concentration), offer the best approach.

Objectives: Validate two process-based models, the ***Integrated Farm Systems Model (IFSM)*** (Rotz et al., 2005, J. Anim. Sci. 83:231) and ***Manure-DNDC*** (Li et al., 2012, Nutr. Cycl. Agroecosyst. 93:163), for predicting daily NH_3 emissions from large, open-lot feedyards in the southern High Plains.

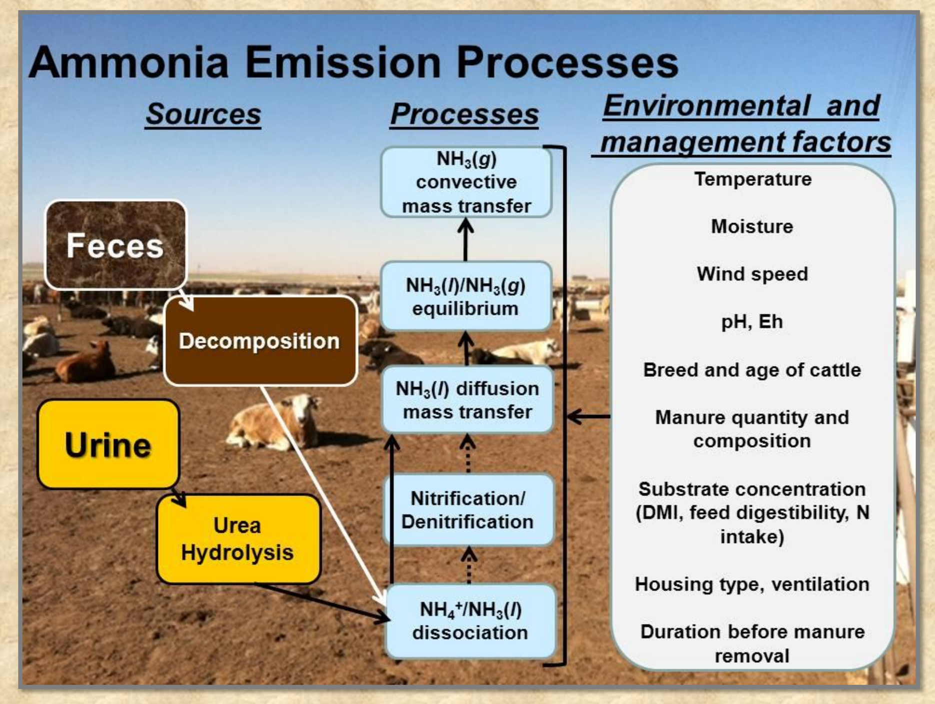

Fig. 1. Processes and factors affecting feedyard ammonia emissions.

Approach: Model predictions were compared to two years of observed NH_3 emissions at two commercial feedyards, **Feedyard A** and **Feedyard E**, in Deaf Smith County, Texas: the top cattle feeding region in the U.S. Observed NH_3 fluxes were determined with open-path lasers and an inverse dispersion model (Todd et al., 2011, J. Environ. Qual. 40:1090).

Primary model input

- Daily weather data: temperature, precipitation, solar radiation, wind speed, etc.
- Average cattle population (one-time capacity):
  - **Feedyard A:** 12,684 head
  - **Feedyard E:** 19,620 head
- %Dietary crude protein (CP): calculated monthly from feedbunk samples (***Fig. 2***)

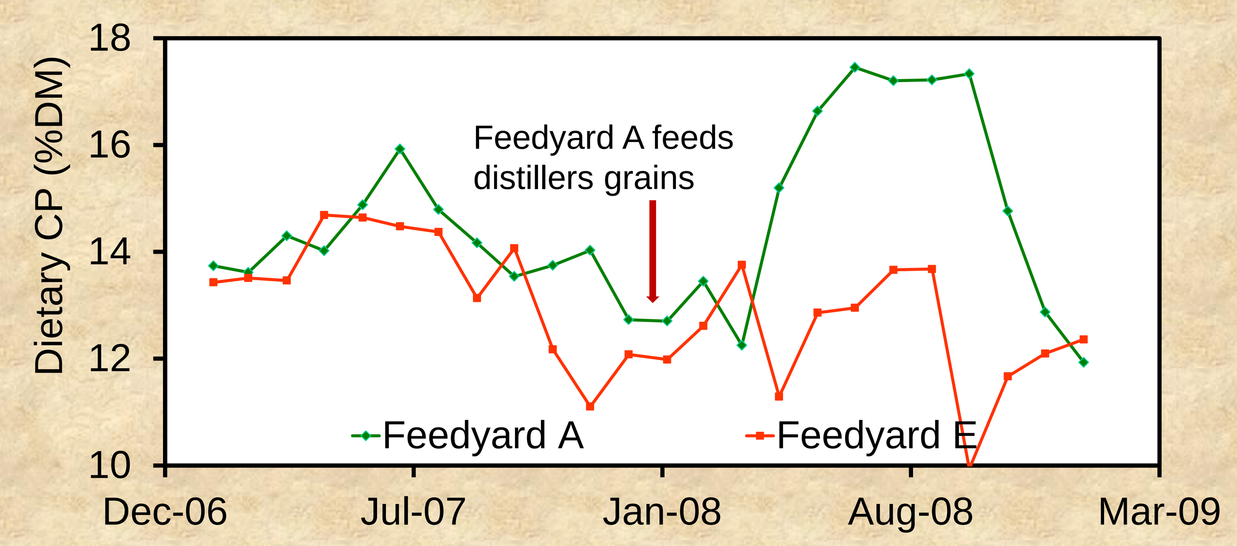

Fig. 2. **%CP fed at the two feedyards.** In 2008, %CP was >18% at Feedyard A due to feeding distillers grains. The NRC recommended level is 12.5 to 13.5% CP.

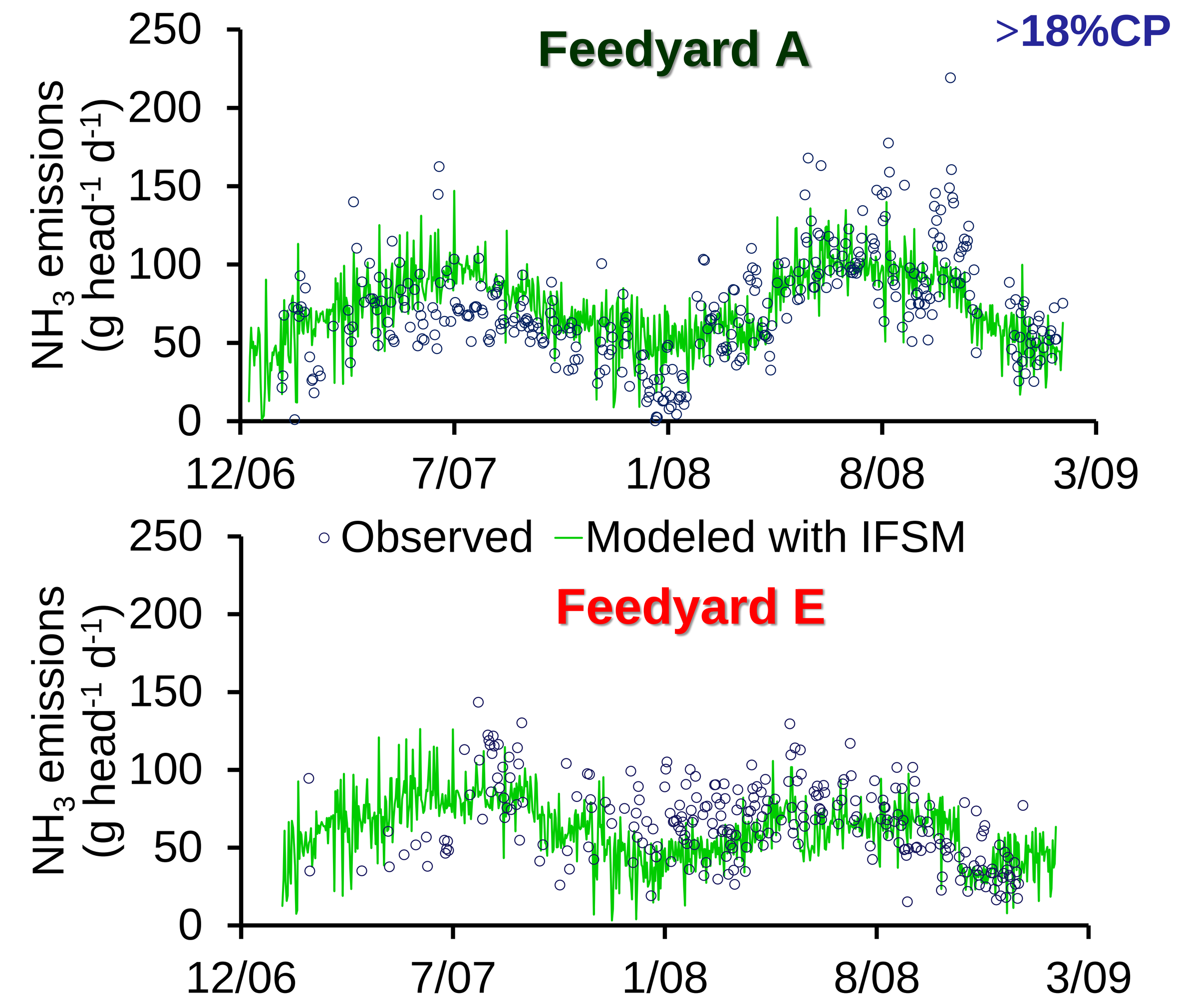

Fig. 3. **Comparison of observed and *IFSM* predicted NH_3 emission rates.** Daily predictions were in good agreement ($p < 0.001$) with observations at both feedyards and responded appropriately to changes in ambient temperature and %CP in feedyard diets.

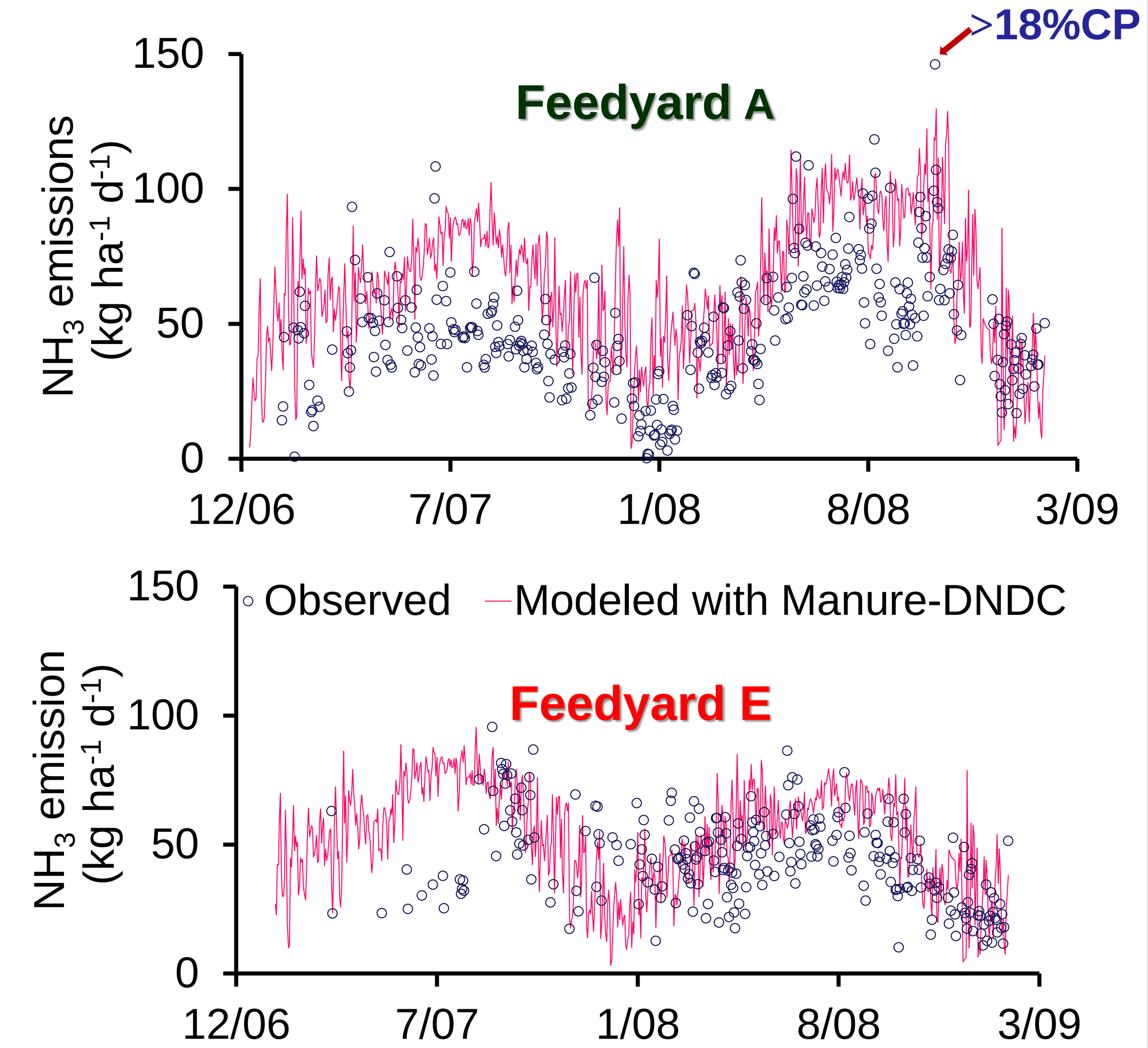

Fig. 4. **Comparison of observed and *Manure-DNDC* predicted NH_3 emission rates.** Similar to IFSM, daily Manure-DNDC predictions for 2008 agreed with observations ($p < 0.001$).

Model and Feedyard	Mean Predicted	Mean Observed	*MAE*[a]	*MBE*	*IA*	R^2
IFSM	---------------g NH_3 head^{-1} d^{-1}--------------					
Feedyard A	77 ± 23	72 ± 34	21.3	-4.30	**0.74**	0.37***
Feedyard E	61 ± 20	66 ± 25	19.0	-6.64	**0.66**	0.23***
Manure-DNDC	-------------kg NH_3 hectare^{-1} d^{-1}---------					
Feedyard A	66 ± 25	48 ± 22	24.3	19.4	**0.68**	0.43***
Feedyard E	53 ± 19	44 ± 17	16.2	8.9	**0.67**	0.24***

[a]*MAE*, mean absolute error; *MBE*, mean bias error; *IA*, index of agreement.

Table 1. **Regression and mean difference comparisons for observed and predicted feedyard NH_3 emissions from Feb. 2007 to Jan. 2009.** The index of agreement (*IA*) indicates 66% to 74% agreement between model predictions and observed emissions. Mean bias error (*MBE*) values show that IFSM tended to slightly under-predict, while Manure-DNDC tended to over-predict summer emissions.

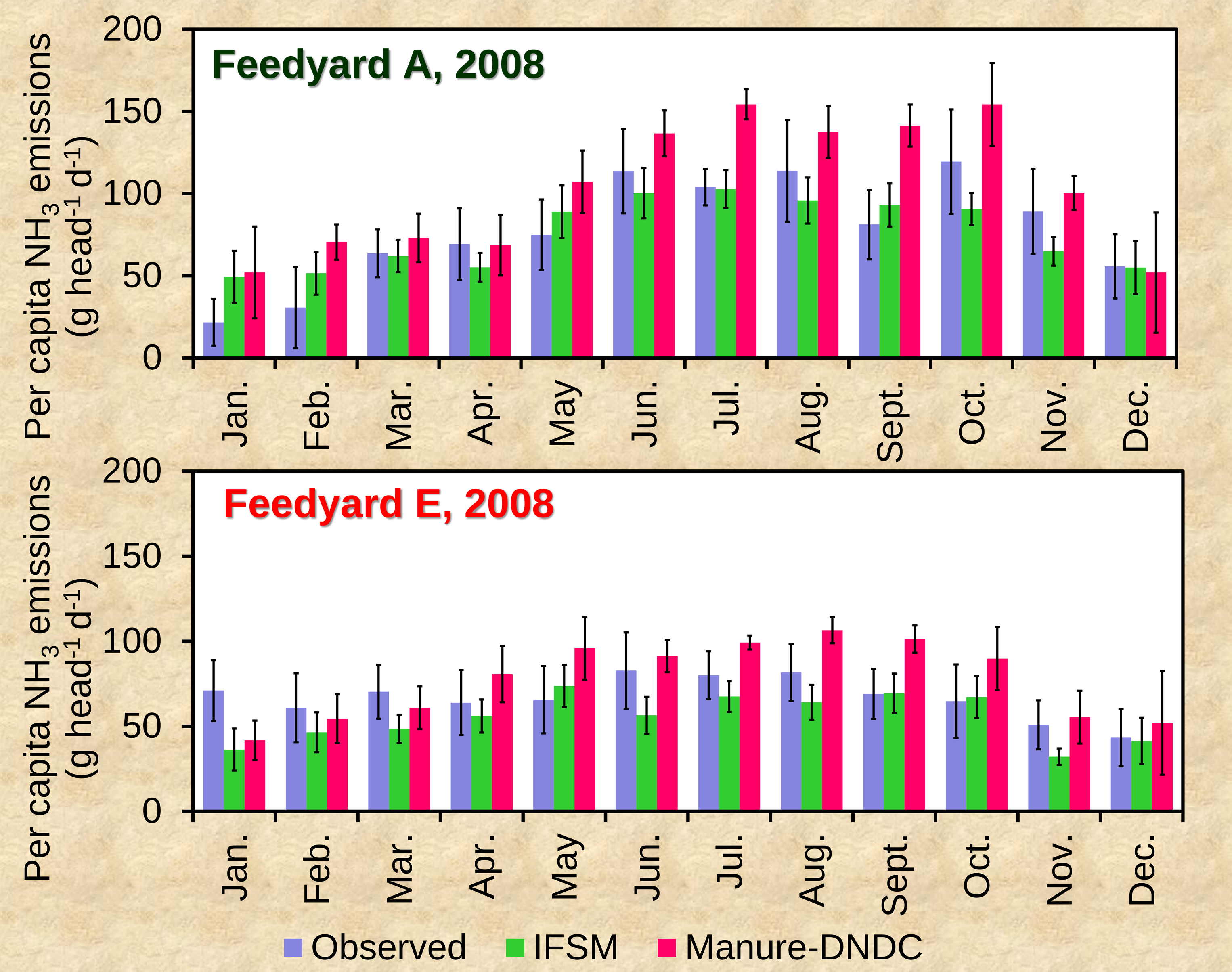

Fig. 5. **Comparison of mean predicted and observed *per capita* NH_3 emission rates from Feedyards A and E in 2008.** Manure-DNDC data were converted to a per capita basis, assuming a stocking density of 15 m^2/head. For most months, model predictions did not differ from observations, indicating that both models were useful for predicting average emissions.

2008 NH_3 Emissions from Feedyard E			
	kg head^{-1} y^{-1}	Mg feedyard^{-1} y^{-1}[1]	Difference (Mg y^{-1})
Observed	28.7	556	----
IFSM	23.1	448	-108 (19%)
Manure-DNDC	32.4	628	+72 (13%)
EPA EF[2]	13.0	252	-304 (54%)

[1]Assumes a one-time capacity of 19,370 cattle and a constant stocking density of 15 m^2/steer.
[2]USEPA, 2005. National emission inventory – Ammonia emissions from animal agricultural operations: Revised draft report. 2005 Apr. 22.

Table 2. **Comparison of observed annual emissions at Feedyard E in *2008* with predictions by Manure-DNDC, IFSM, and the EPA emission factor for beef cattle.** For 2008, IFSM and Manure-DNDC estimates were within 13% to 19% accuracy. In contrast, the current EPA emission factor underestimated emissions by 54%.

CONCLUSIONS

- IFSM and Manure-DNDC predictions paralleled changes in observed NH_3 emissions at both feedyards that were due to temperature and dietary protein (***Figs. 3 and 4***).
- For the period of Feb. 2007 to Jan. 2009 (***Table 1***), IFSM and Manure-DNDC predictions were within **66% to 74% agreement with observations** and there was a significant relationship ($p < 0.001$) between predicted and observed emissions.
- **Both IFSM and Manure-DNDC can be used to quantify average NH_3 emissions from beef cattle feedyards (*Fig. 5*) and are more accurate than current constant emission factors (*Table 2*).**

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