Agricultural Nitrogen Control Practices and Options

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My Assignment

- State of the art for agricultural N emissions
- N emissions control practices
- Costs of control practices and technologies
- *All of that in 30 minutes*

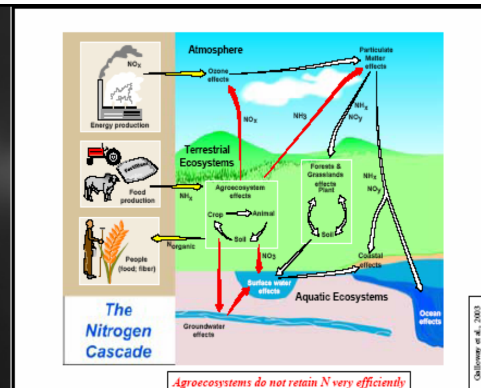
Summary

- Humans mobilize ~50% more Nr than natural terrestrial ecosystems.
  - *Food production accounts for 75%*
- Nr is widely dispersed
  - *Atmospheric Nr emissions have increased 3-fold since 1860; NH_3 twice as important as NO_x*
  - *Nr is accumulating.*

Next Questions

- What are the consequences of Nr emissions on the atmosphere and ecosystems?
- What should/can society do to slow or reverse Nr accumulation?

James Galloway, "Human Alteration of the Nitrogen Cycle: Causes and Consequences," John Airy Symposium, Kansas City, MO, January 2006



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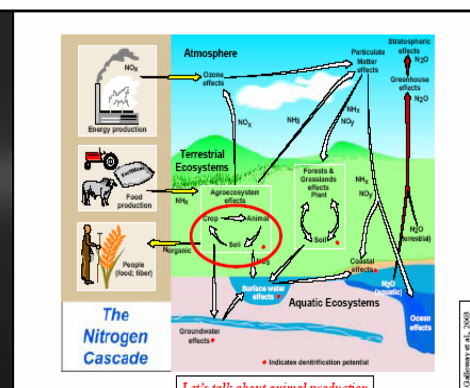
Critical Control Points for Agricultural RNG Emissions

- Crop Production
  - *Farm N balances*
  - Inorganic N fertilizers
  - Manure application
  - Biomass decomposition
- Livestock Production
  - *Farm N balances*
  - Live-animal emissions
  - Open-lot corral surfaces
  - Ventilation exhausts
  - Liquid manure and wastewater storages
  - Composting facilities



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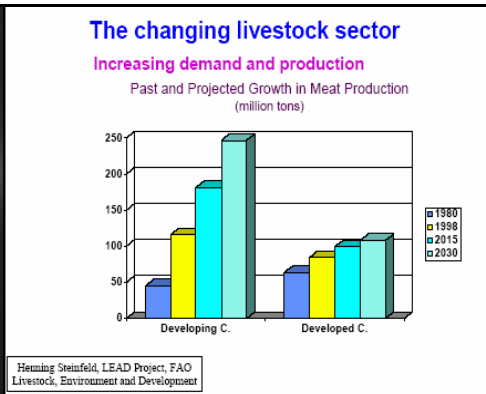

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Air Quality: Dust, Odor and Gases from Open-Lot Animal-Feeding Operations in the Southern Great Plains

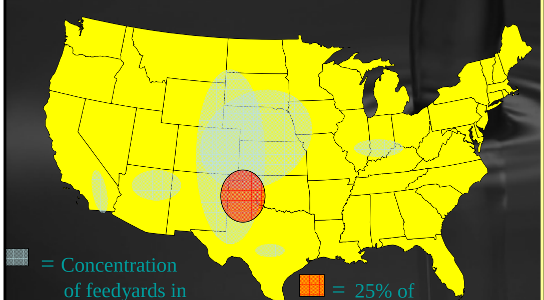
Participants

Texas A&M Ag Program
West Texas A&M University
Kansas State University
USDA Ag Research Service

Major Objectives

1. Emissions Processes
2. Abatement Measures
3. Emission Factors
4. Health Effects
5. Technology Transfer

Fed-Cattle Industry in the US

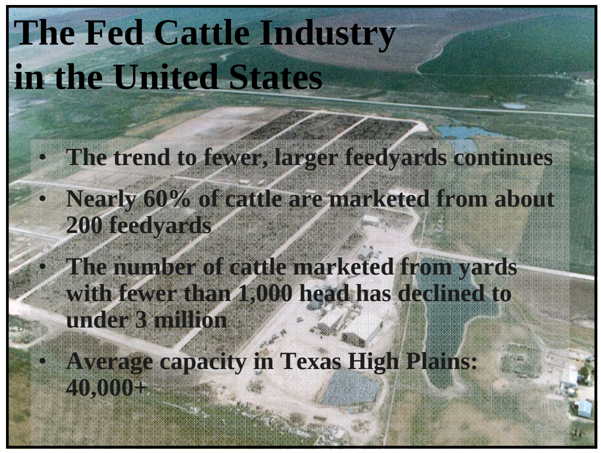


= Concentration of feedyards in U.S.

= 25% of nations beef

Courtesy J. Sweeten (2006)

The Fed Cattle Industry in the United States



- The trend to fewer, larger feedyards continues
- Nearly 60% of cattle are marketed from about 200 feedyards
- The number of cattle marketed from yards with fewer than 1,000 head has declined to under 3 million
- Average capacity in Texas High Plains: 40,000+

Open-Lot Systems

- Beef feedyards
  - Animal spacing 75-250 ft^2/hd
  - Excreted N 90% of N consumed in feed (Bierman et al., 1996)

- Open-lot dairies
  - Animal spacing 200-400+ ft^2/hd
  - Excreted N 70% of N consumed in feed (Van Horn et al., 1996)

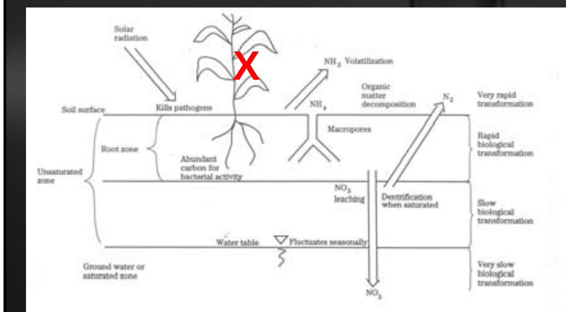
Fate of Excreted N in Open-Lot Systems

- Collected in solid manure
  - Spread
  - Stored (stockpiles, mounds, other)
  - Composted and spread
- Remains on corral surface
  - Stable if it remains dry
  - Runs off into holding pond
- Volatilized as $NH_3(g)$ directly
  - Increases with wet/dry cycling

NH_3 Loss: Open Lots vs. Ponds

- Open lots
  - Large area source, 2-9 acres per 1,000 head capacity
  - Variable emissions driven by wet/dry cycles, short-term temperature fluctuations
- Lagoons and holding ponds
  - Much smaller area source, 1-10 acres *total*
  - Seasonal temperature fluctuations
  - Continuous releases; f(temp, wind speed, RH)

N Transformations on FY Surfaces



Courtesy N. A. Cole and R. Todd (2006)

NH_3 Concentrations Near Alberta Feedyards

- Alberta Environment (2000)
  - One-hour average concentrations
  - Up to ~800 µg m^{-3} NH_3-N
- McGinn *et al.* (2003)
  - Daily averages of 5-minute concentrations
  - Two highest values on days of lowest wind speeds
  - Up to ~1,500 µg m^{-3} NH_3-N

- NH_3 presents steep challenges because of its:
  - High reactivity with anions and surfaces
  - High aqueous solubility
    - Deposition
    - Condensation
  - Kinetically limited redox pathways w/NO_x species
  - Numerous pools and pathways in real systems
  - Sensitivity to pH
- Accounting for all of those factors in a single measurement scheme is complicated
- Uncertainty analysis assumes all sources of bias (systematic error) have been eliminated

NH_3 Flux Estimates by 5 Methods

Courtesy N. A. Cole and R. Todd (2006)

The Holy Grail

A range of emission factors that expresses the most probable, scientifically justifiable, annualized, NH_3 emission flux from feedyards and dairies as a function of herd size, stocking density or other appropriate measure of capacity or throughput

Where We Are Today

- There are dozens of different ways of estimating NH_3 flux from an open-lot AFO
- Today, we consider results from several of them
- Getting at the *true flux* requires a convergence of results from independent methods, but even that's not enough

Available Methods

- Envelope approaches
  - Mass balance
  - Nutrient ratio (N:P)
- Direct approaches
  - Surface isolation flux chambers
  - Wind tunnels
  - Eddy covariance
- Dispersion/box models
  - Gaussian (ISCST, AERMOD)
  - Lagrangian stochastic – backward, forward
  - Integrated horizontal flux (IHF)
  - Flux-gradient
  - Box

Mass Balance Equation for Open-Lot AFOs

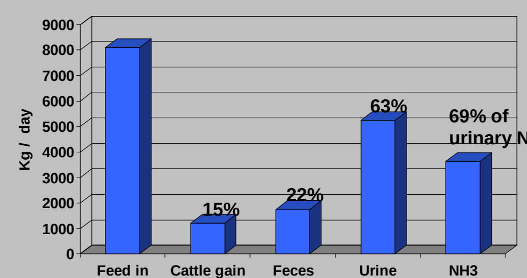
Excr. Coef. | Total N Intake (Feed, Water)

$$M_{AT} = 1.21(1-\gamma_{RN})\left\{\left[\frac{C_{CP}\bullet M_{DMI}}{6.25}\right]+\left[\frac{M_W\bullet C_{WN}}{10^6}\right]\right\}\{\gamma_{EUN}\gamma_{UNV}+(1-\gamma_{EUN})\gamma_{FNV}\}$$

Total N Excretion

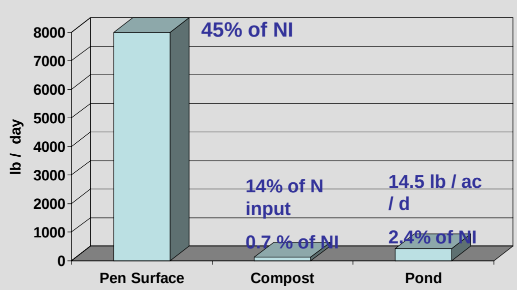
Partitioning and Volatilization Coefficients

Feedyard N Balance



Courtesy N. A. Cole and R. Todd (2006)

Daily Volatile N Losses



Courtesy N. A. Cole and R. Todd (2006)

Method	Beef	Dairy	Comments
	% of Fed N		
N Balance	44	<80	Uncertainty analysis nearly complete (beef)
N:P Ratio	48		Varies from 20-51% depending on source material (fresh manure, pen surface, compost)
Flux Chamber	18	3 (OL) – 5 (FS)	Herds are ~15% dry cows, ~85% lactating; excreted N is 79% of fed N
Flux-Gradient	43		Uncertainty analysis underway
bLS/OPL	41		Uses open-path lasers to measure N
Box Model	31-55		

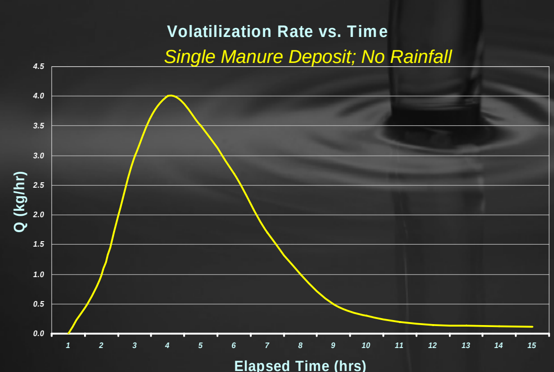
Urine-Spot NH_3 Emissions

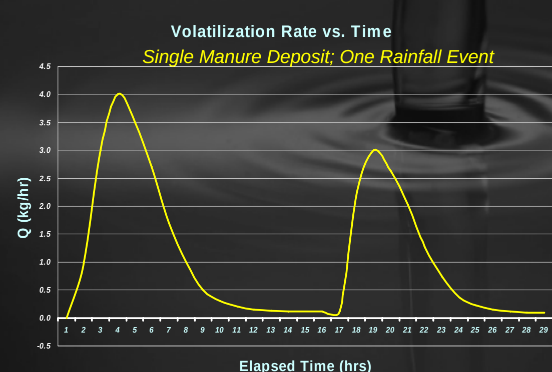
- The vast majority of NH_3 emissions comes from urine spots
- Surface chemistry changes rapidly
- Accurate measurements of NH_3 (and CH_4, NO_x) flux are needed to develop appropriate models and make valid treatment comparisons

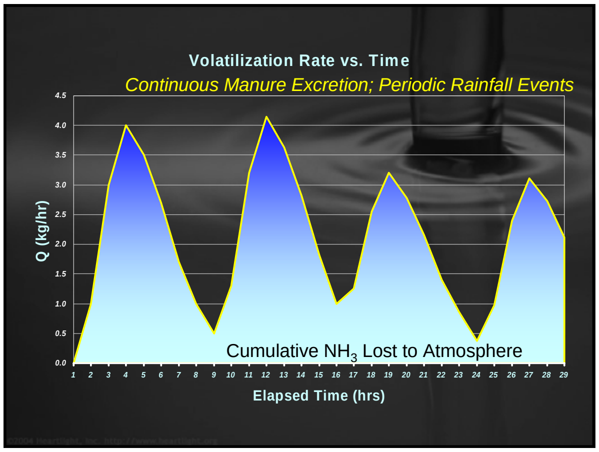
Courtesy N. A. Cole and R. Todd (2006)

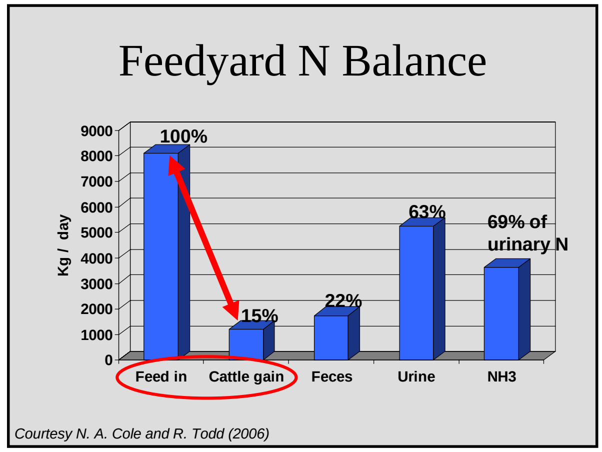
Open-Lot NH_3 Flux: Drivers

- Wet/dry cycles
- Low C:N ratio of manure
- Favorable pH (>7.0)
- Enzyme-mediated hydrolysis of urea
- NH_4^+ highly soluble, mobile



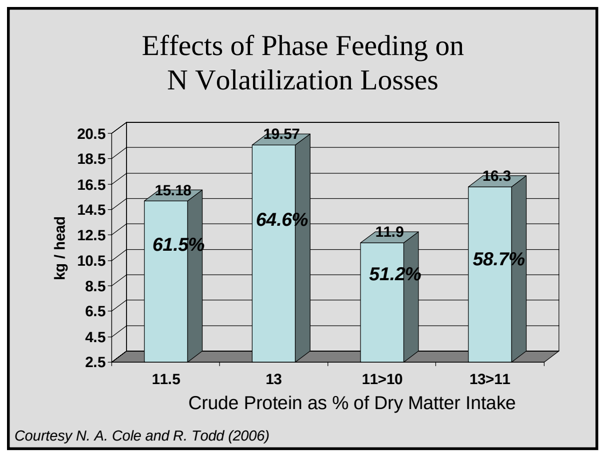






Reducing Open-Lot NH_3 Flux

- Wet/dry cycles: *Stop H_2O applications, improve corral drainage*
- Low C:N ratio of manure: *Add carbonaceous bedding, mulch or liquid source of organic C (e. g., humates)*
- Favorable pH (>7.0): *Alum or other*
- Enzyme-mediated hydrolysis of urea: *Urease inhibitors*
- NH_4^+ highly soluble, mobile: *Add strong adsorption sites (e. g., clinoptilite)*



Surface Amendments

- Shi et al. (2001) – *in vitro* evaluations of simulated feedyard surfaces
  - $Al_2(SO_4)_3$ – lowers manure pH
  - NBPT – suppression of urea hydrolysis to NH_4^+
  - $CaCl_2$ – cation exchange
  - Humate (black and brown) – increase C:N ratio
- Measured cumulative loss over 21 days
- Incremental benefit computed as equivalent N fertilizer maintained in manure; rises and falls with NG/anhydrous prices
- Does not factor in the presence of carbonaceous bedding *as is common in Alberta feedyards*

Results of Shi *et al.* (2001)

- Alum: 92% reduction at 4,500 kg/ha; B/C=0.17
- CaCl2: 71% reduction at 4,500 kg/ha; B/C=0.16
- *NBPT: 65% reduction at 1 kg/ha; B/C=1.75*
- Humates: 65% reduction at 9,000 kg/ha; B/C=0.04

Surface Amendments

- Replicating NBPT success outside the laboratory has been unsuccessful so far
- Keeping N as urea in manure surface would increase N pool and require increasing application rates over time
- Urea in solid manure can reduce NO_x emissions from coal-fired power plants during reburn

Reducing Open-Lot NH_3 Losses

- Wet/dry cycles: *Stop H_2O applications, improve corral drainage*
- Low C:N ratio of manure: *Add carbonaceous bedding, liquid C source (humates; dilute beet extract?) or mulch*
- Favorable pH (>7.0): *Alum or other*
- Enzyme-mediated hydrolysis of urea: *Urease inhibitors*
- NH_4^+ highly soluble, mobile: *Add strong adsorption sites (e. g., clinoptilite)*
- Extensive area source: *Manure harvesting*

A Reminder to Alberta's Policymakers

- We can design innovative stuff…
- … but *can we afford it* at current levels of energy use?
- What about at *future* levels?