

Identifying Modeling Gaps and Building Better Tools Through Partnerships

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Report and White Papers on Animal Management and WQT

Primary report:

- Refining Models for Quantifying Water Quality Benefits of Animal Management for Water Quality Trading

Supplemental White Papers/Briefs

- Management Options for Animal Operations to Reduce Nutrient Loads
- Assessing Potential Impacts of Livestock Management on Groundwater
- Management Practices to Improve Water Quality on Central and Western Rangelands

All reports available at <http://nicholasinstitute.duke.edu>

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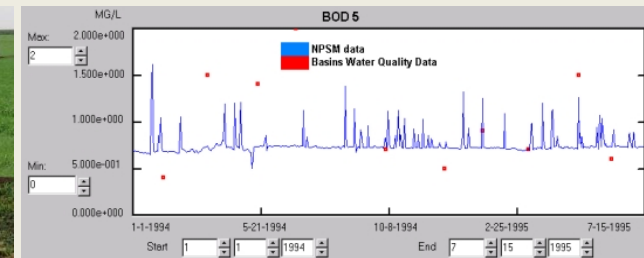
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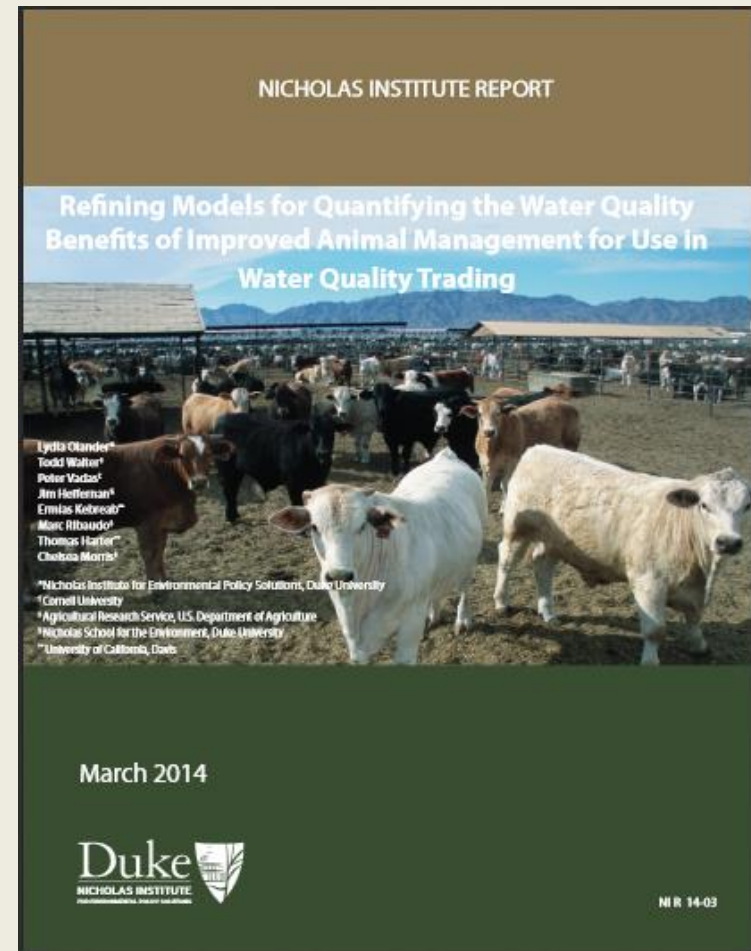
Goals

- Provide overview of existing measurement methods and models for quantifying water quality changes in animal operations for WQT
- Academic review of models and methods, **not** practical guide for using tools in WQT
- Inform possible efforts to build updated and more integrated methods and models



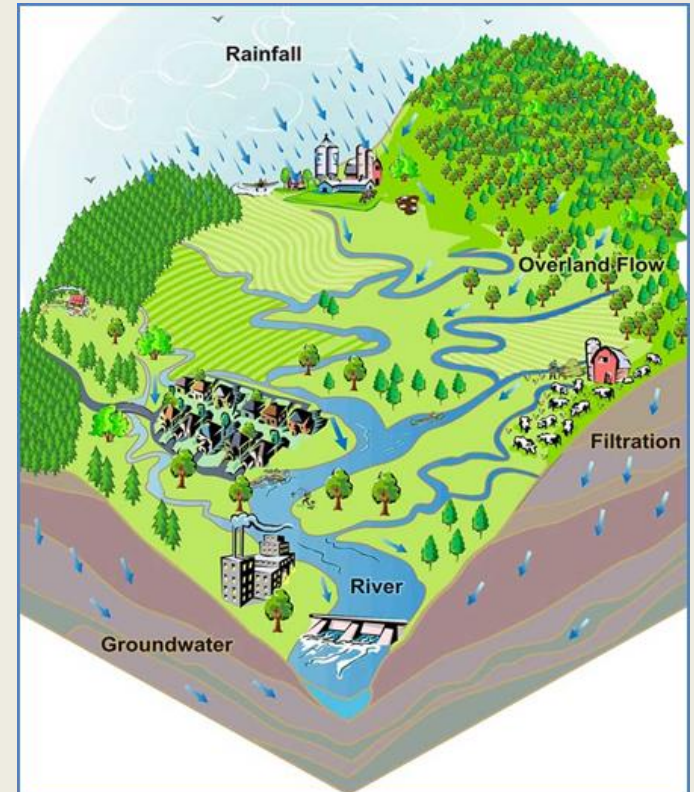
Report Sections

1. Animal agriculture: Water quality impacts, water quality trading, and quantification methods
2. Methods and models for estimating nutrient loading from animal facilities
3. Monitoring and measurement
4. Building better quantification tools



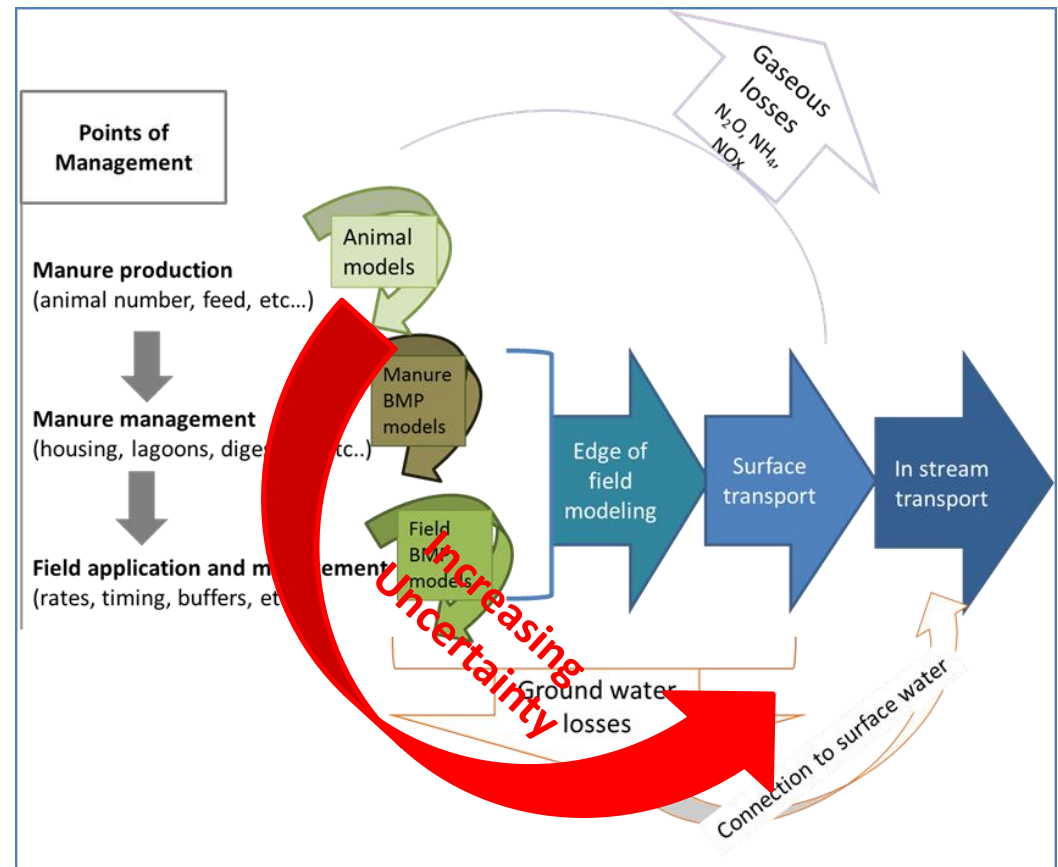
Background

- How is Water Quality Affected by Animal Operations
 - Overview of N and P, sources, modes of transport, chemical forms
- Clean Water Act, Animal Operations, and WQT
 - How animal operations relate to CWA, NPDES, TMDL
 - WQT – what it is and how it works in relation to animal operations



How Changes in Pollutant Loads can be Quantified

- Different types of practices need quantification
 - Many of these can be combined
- Need multiple combined or nested models



Animal and Manure models

- Amount and nutrient content of manure
 - Measurement
 - Calculated Mass Balance
 - (feed intake – milk output = manure)
 - Predictive Empirical
 - Predictive Mechanistic (IFSM, DNDC)
- Effects of manure management
 - Need to incorporate wide range of actions
 - where manure is deposited, how it is collected and stored, and processed before land application or transport
 - Empirical models or look up tables
 - Mechanistic models (IFSM, DNDC)



Surface transport Models

- Types of models
 - Small independent homogeneous agricultural fields
 - Lump watershed heterogeneity into average characteristics
 - Distributed or quasi-distributed parcel level differentiation
 - Event based; continuous time, quasi steady state, long term averages
- Models
 - Many models use CN or USLE sub models
 - Adapt-N and Phosphorus indices
 - Annual Phosphorus Loss Estimator (APLE)
 - CREAMS/GLEAMS
 - EPIC/APEX
 - WEEP
 - IFSM



Watershed Transport Models

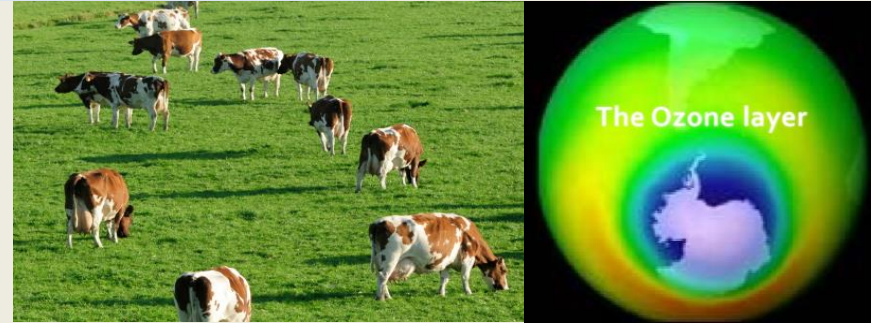


- Why Watershed models needed
 - To capture effect of animal and field scale management on WQ
 - To capture off field management (constructed wetlands, riparian buffers)
- More challenging
 - Need significant modeling experience and input data
 - Need calibration which requires and monitoring data
 - “getting right answer for wrong reasons”
 - Considerable uncertainty on the effect of management – especially with respect to landscape position
 - Now best suited for large landscape scale changes – not field/parcel scale estimates for WQT
 - However, are improving and may be useful for WQT moving forward
- Main models
 - GWLF, SWAT, HSPF, ISSm, and WARMF

Other Considerations

- Grazing Systems

- Different watershed models
- KINEROS2; RHEM



- Unintended consequences

- Modeling can also be use to assess the risks of shifting pollutant loads to groundwater or airborne emissions (NO_x , N_2O , NH_4)
 - Groundwater models (map areas of vulnerability, empirical estimates, mechanistic methods, and 3-dimensional simulation)
 - System models that include air emissions (DNDC, IFSM, DayCent)
- Can allow programs to avoid areas or activities that present high risks of other problematic loss pathways

State of Modeling

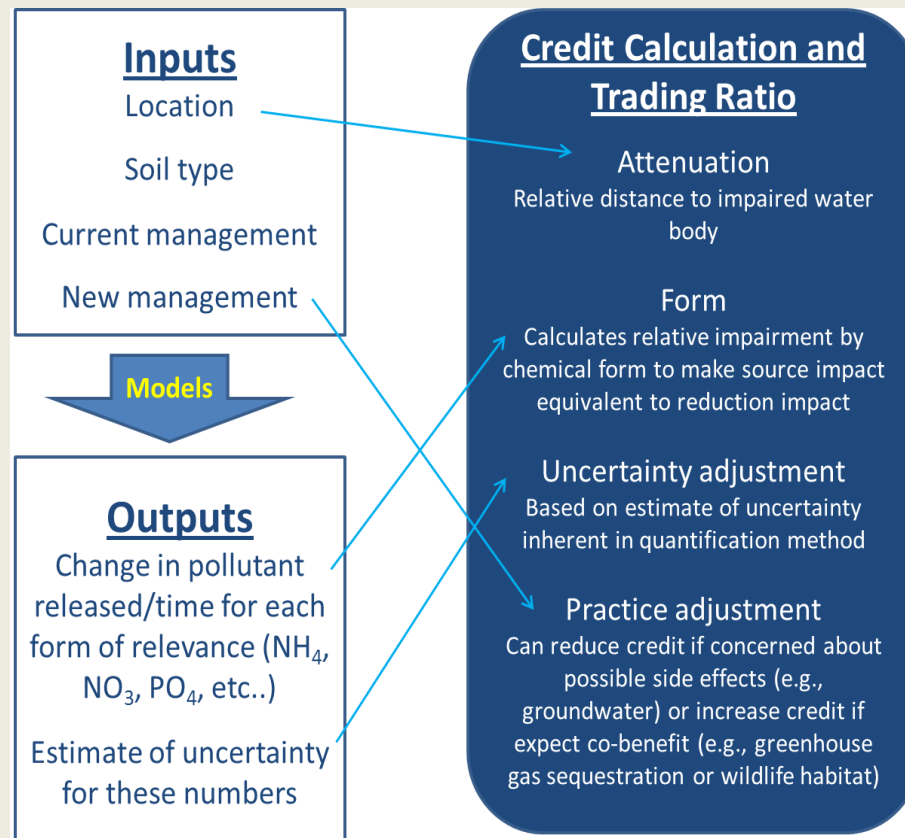
- WQ models continually evolving
- Predictions generally more reliable at animal to field scales
 - Examples - EPIC, ISFM
- Watershed models considerably more uncertain
 - Complexity requires expert modelers
 - May not capture field scale changes
 - Lack of understanding and appropriate modeling of important processes
 - Runoff distribution
 - Riparian denitrification
- Model improvements are available
 - New research models could help - TOPMODEL, SMR, RHESSys – require resources and commitment to maintain and distribute models

Working with current models

All models have errors and uncertainty. This should not prevent use of otherwise well developed model

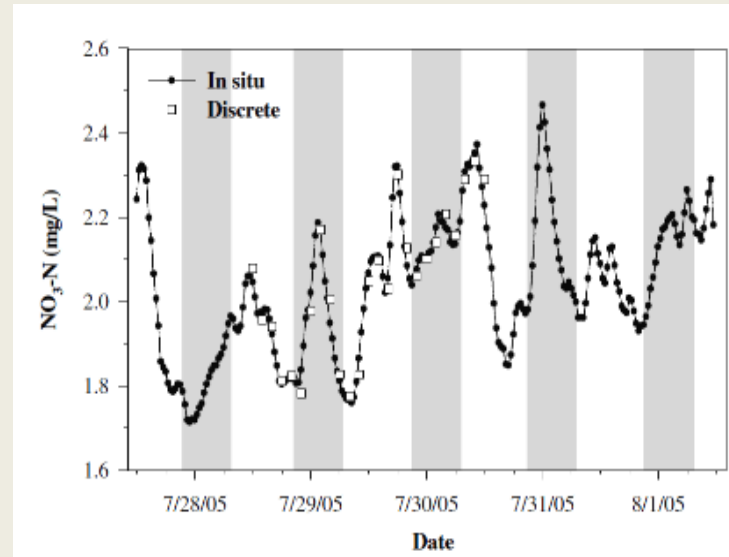
Addressing uncertainty and risk

- Uncertainty adjustment
- Practice adjustment
 - To account for potential side-effects or co-benefits



Use of Direct Measurement

- Current Role
 - Calibrate, improve models
 - Assess effectiveness of WQT program
 - Practice-specific measurements
- Not always appropriate (cost, time) for WQT now, but advances may change that
 - Remote sensing
 - In-situ water quality sensors (high frequency data)



Hourly measurements of nitrate concentration over a five-day period in the San Joaquin River, California

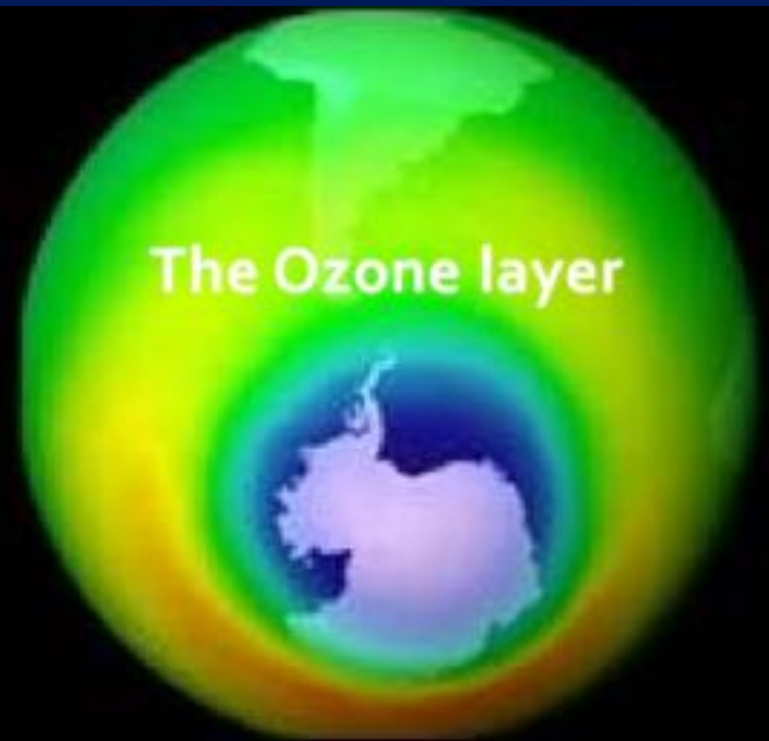
Source: Pellerin et al. 2009

Using & Improving Models

- 12 Important model characteristics for WQT:
 - Does model adequately represent pollution load reductions?
 - Does model represent local conditions, systems, and practices?
 - Are model sensitivity and uncertainty appropriate for desired pollutant reductions?
 - Does model deliver information in same units and on same timescale as WQT?
 - Is model user-friendly, practical, and economical enough?
 - Does it give consistent results across multiple users for same scenarios?
- No model meets all criteria, but this can be guide for selection and for model improvement

Priorities for better tools

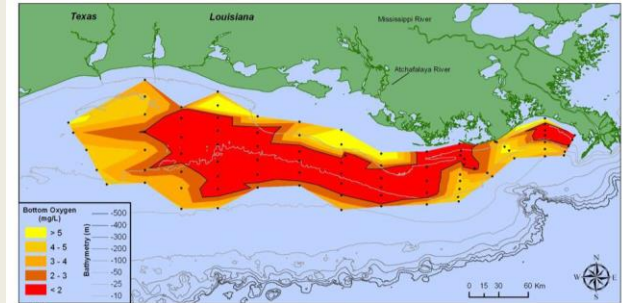
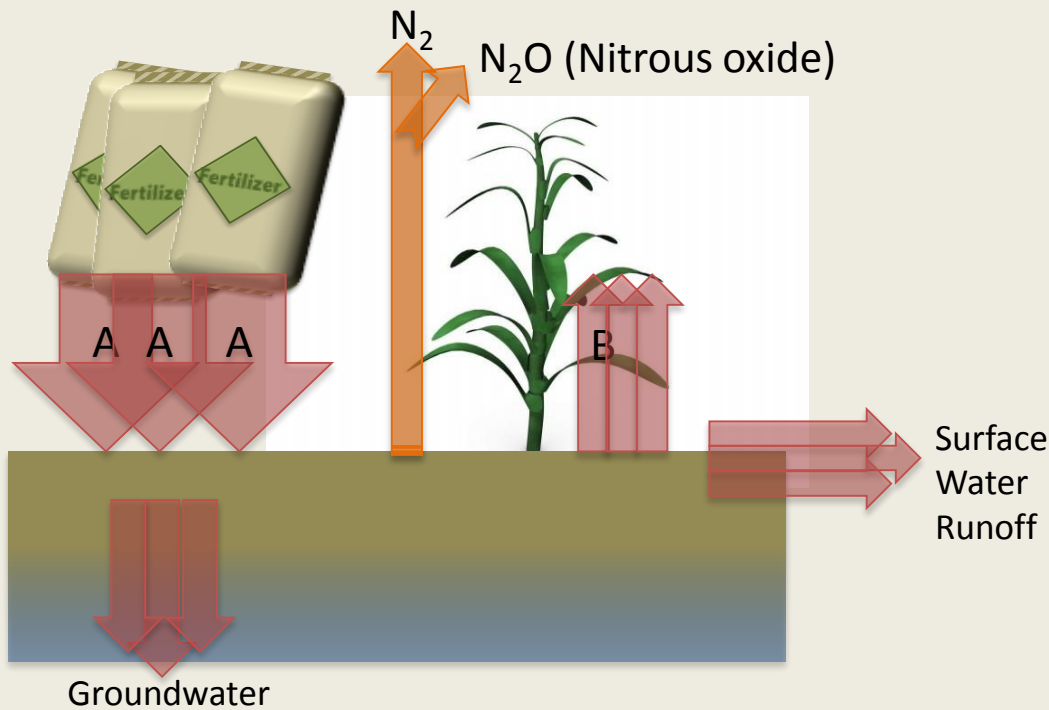
- Runoff: Alternatives to CN approach (TOPMODEL).
- Erosion: Improvements to the USLE models.
- Better link between field practices and water quality at watershed outlet.
- Mechanistic models often generates a more robust, dynamic model
- Uncertainty Estimates for full confidence in predictions.
- Linking surface water predictions to groundwater and air as needed
- Update old model code and foundations (spatial, online, modular)



Improving quantification of agricultural nitrous oxide emissions for GHG markets and supply chain initiatives

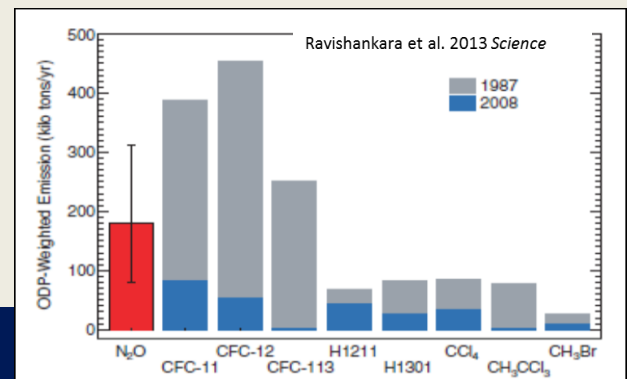
PART 2

N management for GHG offsets and supply chain

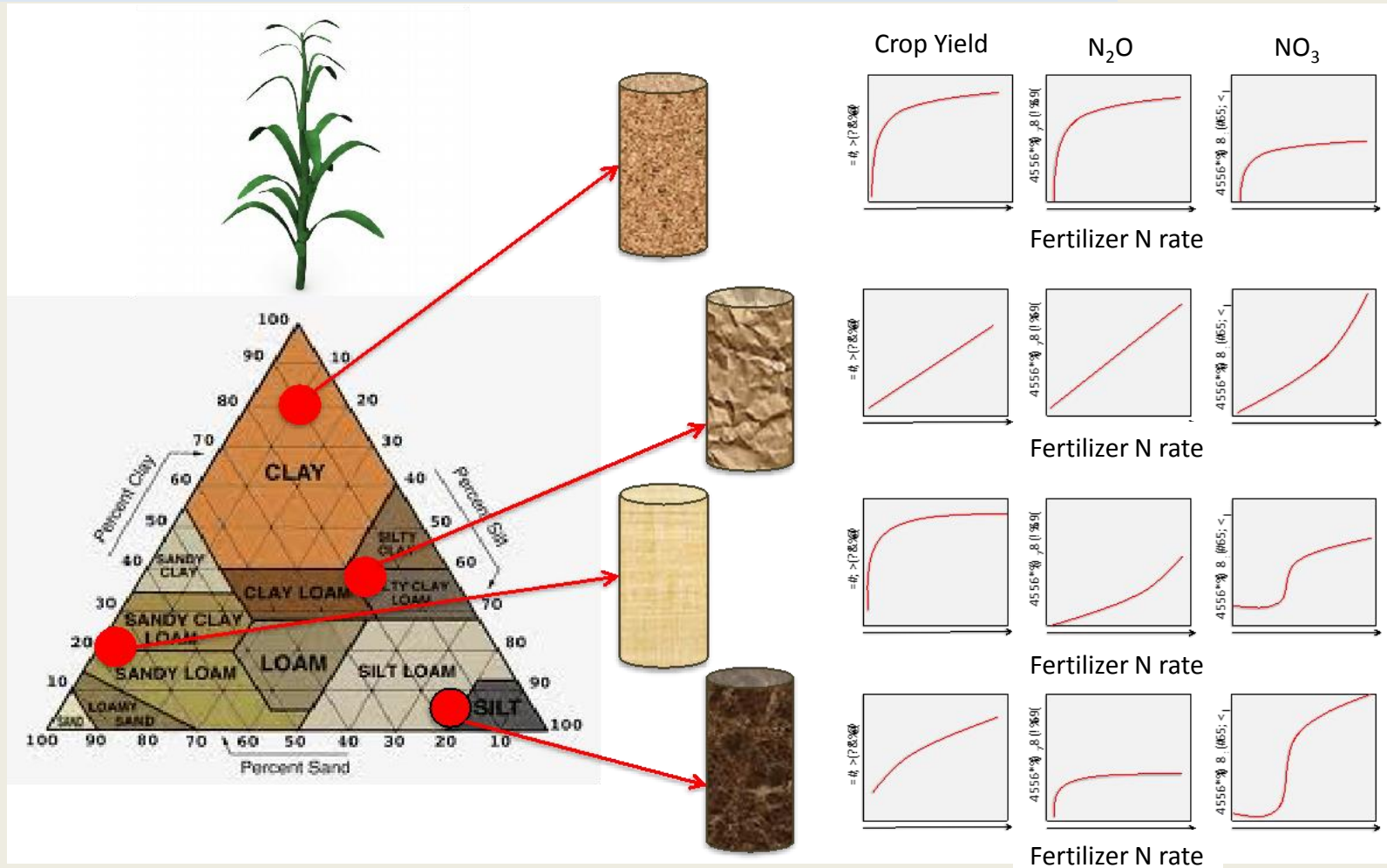


GWP* values and lifetimes from 2013 IPCC AR5 p1071
(with climate-carbon feedbacks)

	Lifetime (years)	GWP 20 years	GWP 100 years
Carbon Dioxide (CO_2)		1	1
Methane (CH_4)	12.4	86	34
Nitrous Oxide (N_2O)	121	268	298

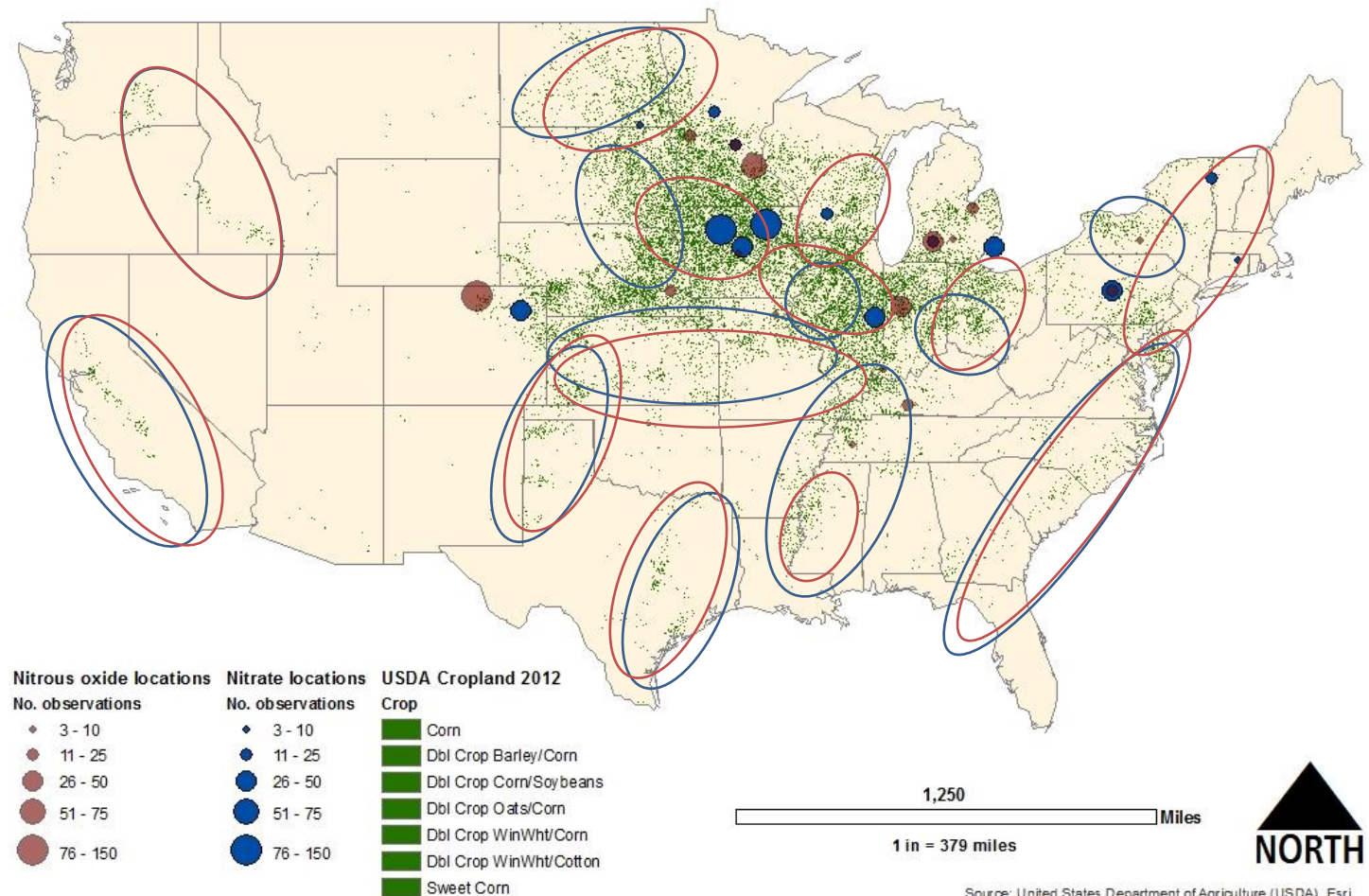


Expect N losses to vary with soils and climate



Data gaps

Locations of nitrate leaching and nitrous oxide emission studies for 4R project



Source: United States Department of Agriculture (USDA), Esri

How to improve?

Models need more calibration and validation data from more places

Need collaboration between modelers, ecosystem scientists, and agricultural research community

1. National scale lab analysis of potential N losses from major soil types and regions.
 - Combining different N measurements help constrain models (mass balance)
2. Field studies to verify and assess natural variability and effect of extreme events (drought, flood)
 - Using simulated field events and a small set of long term sites