SDP Modeling Update

Year 2 CNH Workshop

5/31/17-6/2/17

Madison, WI

Model structure

- Nonlinear constrained optimization problem
- Agents choose: 1) allocation of land among crops, and 2) fertilizer applications to maximize profit subject to resource constraints
- Simple annual problem:

$$\max_{l_c, N_c} \sum_c \{p_c \cdot yield_c(l_c, N_c) - (r_N \cdot N_c + r_l \cdot l_c + vc_c - fc_c)\}$$

$$s.t. \sum_c l_c \leq L, \sum_c N_c \leq N$$

$$l_c \geq 0, N_c \geq 0 \; \forall c$$

Model structure

Regional-scale (aggregate) model	Field-scale (individual) model
• Single optimization problem	• Separate optimization problem for each field
• l_c: proportion land in each crop rotation	• l_c: indicator for crop grown
• Static (crop yield depends on rotation)	• Dynamic (crop yield in year *t* depends on crop grown in year *t*-1)
• Calibration with Positive Mathematical Programming (PMP)	• Calibration relies on yield differences across fields (e.g., from heterogeneity in land quality)

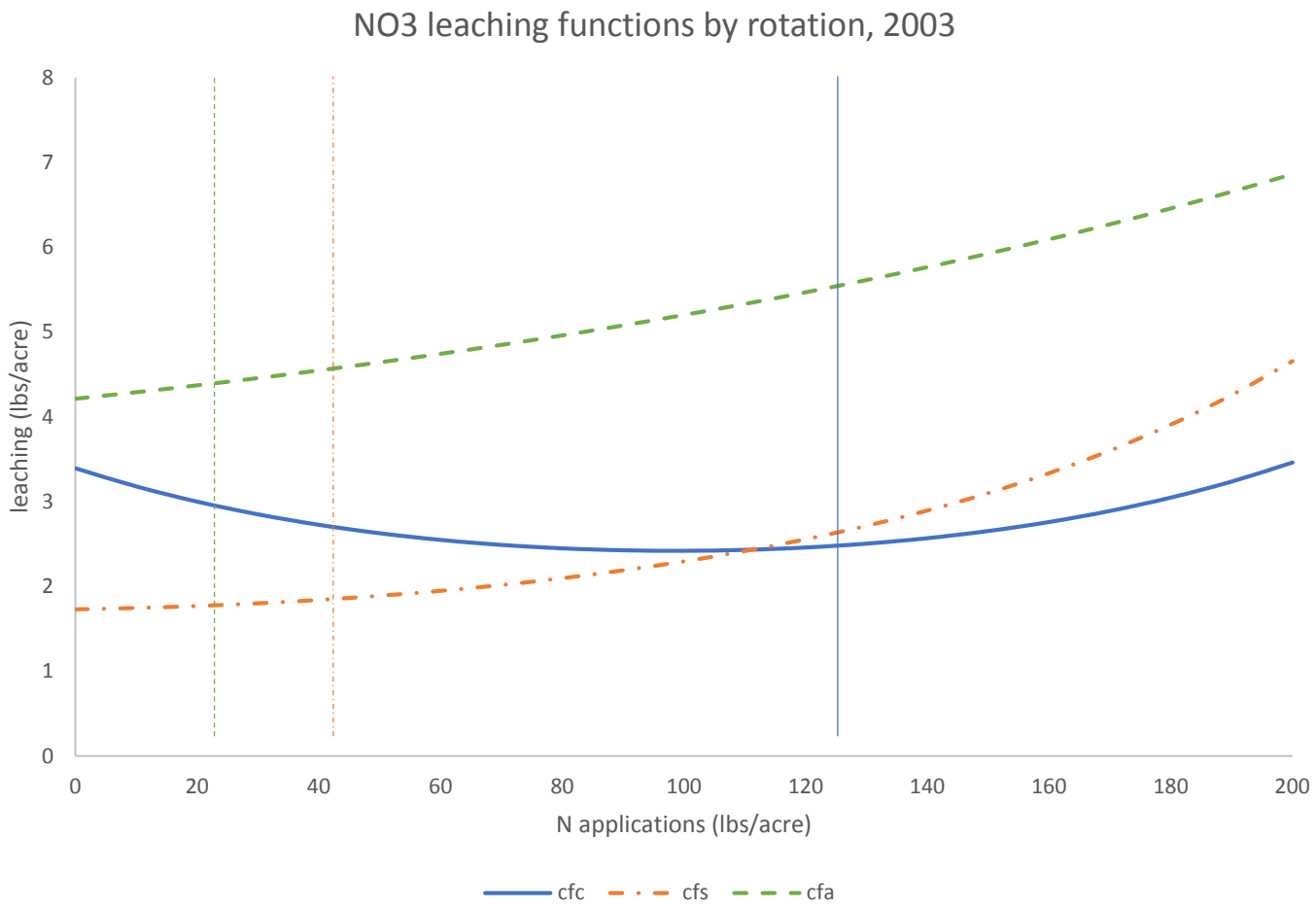
Approach

- Regional (aggregate) model

- Data
  - Cycles simulation output: yield, NO_3 leaching, N_2O emissions by crop, rotation, year (weather), and total N applied for 1980-2015
    - Mitscherlich-Baule yield functions estimated using nonlinear least squares
    - Log-linear leaching and emissions functions estimated using ordinary least squares
  - Regional average/recommended fertilizer applications by crop and rotation
  - Crop rotations based on USDA Cropland Data Layers (Kemanian, Rozum, and White)
  - Costs of production from UW Extension budgets by crop and rotation
  - Crop prices from USDA NASS annual surveys by crop

Estimated functions

Estimated functions



Approach

- PMP calibration
  - Addresses tendency toward corner solutions
  - Captures unobserved factors that affect decision-making
  - Replicates observed land allocation by crop rotation based on USDA Cropland Data Layers (Kemanian, Rozum, and White)
    - 67.4% continuous corn
    - 8.4% corn-soy
    - 24.2% corn-corn-corn-alfalfa-alfalfa-alfalfa
  - Calibrating on land results in recommended fertilizer applications

Results, baseline model

Land allocation		Fertilizer applications		Yield	
Continuous corn	0.674	Corn after corn	125.16	Corn after corn	138.49
Corn-soy	0.084	Corn after soy	41.43	Corn after soy	134.74
Corn-alfalfa	0.242	Corn after alfalfa (avg)	20.34	Soy after corn	48.38
				Alfalfa after corn	3.97
				Alfalfa year 2	4.54
				Alfalfa year 3	4.39
				Corn after alfalfa (avg)	126.73

Results, baseline model

Baseline model	30% N reduction, no adjustment in land allocation
Production Corn 114.34 bu/ac Soy 2.03 bu/ac Alfalfa 0.52 t/ac N applications 88.56 lbs/ac Profit $111.86/ac Leaching 2.45 lbs/ac Emissions 1.19 lbs/ac	Production Corn 101.65 bu/ac Soy 2.03 bu/ac Alfalfa 0.52 t/ac N applications 41.76 lbs/ac (on continuous corn only) Profit $72.32/ac Leaching 1.83 lbs/ac Emissions 0.40 lbs/ac