# Optimal Nitrogen Applications: A Stochastic Dynamic Model of Irrigated Corn in the Southern High Plains

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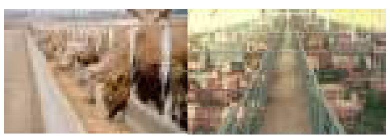
## Introduction

- ❑ Regional importance of livestock production
  - ❑ Swine production, along with beef cattle, generated $636.7 million in revenue and was the major source of employment, providing nearly 16 000 jobs within this area (Oklahoma Pork Council, 2009, unpublished data).
- ❑Economic feasibility of animal manure as a substitute for commercial fertilizers
  - ❑ The proper management is costly and labor intensive (Carreirea, 2004).
  - ❑ Not as efficient as commercial fertilizers since some nutrients in animal manure are not available for plant uptake (Zhang, 2003).
- ❑ Best management practices of animal manure applied to land
  - ❑ Imperative in the semi-arid areas where crop and animal production is heavily dependent on limited water resources.



## Previous studies

- ❑ Non-market valuation methods
  - ❑ Animal manure as a substitute for commercial fertilizer (Ruter et al., 2004; Nunez and McCann, 2004).
- ❑ Few classical primal approach to utilization of nutrients in the animal manure
  - ❑ Lack of the multi-year soil data (Carreirea, 2004).

## Objective

- ❑ Using a stochastic dynamic programming (SDP) model, this study determines optimal nitrogen fertilizer rates in continuous irrigated corn according to sources of nitrogen (anhydrous ammonia, beef, and swine manure).
  - ❑ Estimated corn response and soil nutrients (N, P, pH) carryover functions for each source of nitrogen are used in a SDP model

## Optimization Model

- ❑ Maximize expected utility of net return over time
- ❑ A set of equations for state (carryover) variables
  - ❑ Soil nitrogen, Soil phosphorus, Soil pH
  - ❑ Power utility function defined as $\frac{(\pi_t)^{1-\Theta}}{1-\Theta}$
    $\Theta$ is the coefficient of relative risk aversion
  - ❑ Modified Mitscherilich-Baule response function
  - ❑ Nitrogen loss function through ammonia volatilization for swine effluent
  - ❑ Nitrogen application cost
    - ❑ assumed to be linearly related with Na

## Data

- ❑ Multi-year data with yield of irrigated continuous corn and soil characteristics
  - ❑ Oklahoma Panhandle Research and Extension Center (OPREC) near Goodwell, OK
  - ❑Three sources of nitrogen fertilizer
    - ❑ Anhydrous ammonia (AA), Beef manure(BM), and swine effluent (SE)
  - ❑ Four different application rates of nitrogen fertilizer
    - ❑ 0, 56, 168, and 504 kg ha $^{-1}$ yr$^{-1}$
  - ❑ Randomized complete block design with repeated measures.

## Numerical Algorithm

- ❑ Stochastic Dynamic Optimization :
  - ❑Dimensions and bounds of discrete grids

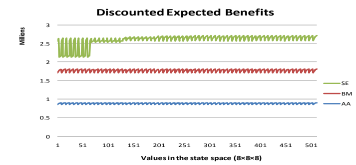
| | State Variable Grids | | | Control Variable |
|---|---|---|---|---|
| | N (Kg N /ha) | P (Kg N /ha) | pH | Opt_NA (Kg N /ha) |
| Min Value | 10 | 27 | 5 | 0 |
| Max Value | 200 | 800 | 8.5 | 200 |
| No. of points | 8 | 8 | 8 | 12 |

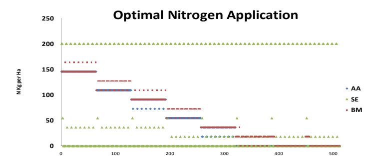
- ❑ Four random shocks: Fourth-order Gaussian approximation of the distribution was used
- ❑ A Markov transition matrix
  - ❑ the stochastic nature of the state-transitions and the linear interpolation to approximate $EV_{t+1}(N_{t+1}, P_{t+1}, pH_{t+1})$
- ❑ A complete conditional Markov transition matrix for each of the 12 value
  - ❑ A 512×512×12 array of possible dynamics
  - ❑ A 512×12 array of possible expected utility
  - ❑ In each iteration of a successive approximation approach to find the optimal NA for each of the 3 N sources.
- ❑ Bellman's equation

$$V^{k+1}(N_t, P_t, pH_t) = \max_{NA_t} R(N_t, P_t, pH_t, NA_t) + \beta E V^k (N_{t+1}, P_{t+1}, pH_{t+1})$$

  - ❑where $\beta$ is the discount factor, if $r$ is the discount rate. $\beta = 1/(1+r)$
  - ❑ $k$+1th approximation of the value function is found by finding the $NA_t$, that solves the Bellman's equation
  - ❑ Solved for each of the 512 points in the state space and then the process is repeated recursively until a fixed point is reached until $V^{k+1}(\cdot) \approx V^k(\cdot)$

## Results




## Conclusion

- ❑ Best source of nitrogen is swine effluent
  - ❑ Consistent with previous findings ( Park et al 2010, Park 2009).
- ❑ For anhydrous ammonia and beef manure, the optimal NA rate depends only on the soil Nitrogen levels.
  - ❑ No variation w/r/t soil pH or soil Phosphorus levels.
- ❑ For swine effluent , soil pH seems to be a driving force
  - ❑ Optimal NA rates move between max and min values

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