Quantifying the Long-term Effect of Management on N Loss and Corn Production

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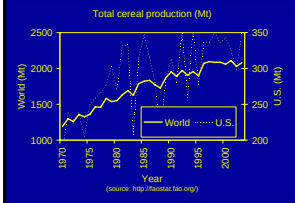
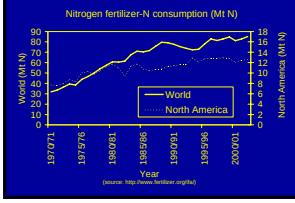
Fertilizer-N use

"What has been the most important technical invention of the twentieth century…synthesis of ammonia" –Smil, 2001

It is estimated that about 40% of the current global population would not be able to survive (let alone thrive) without fertilizer production
(Smil et al., 2001).

Fertilizer-N use





Projections

- The U.S. population increase - 80 million between 2000 and 2030 (http://www.census.gov/ipc/www/usinterimproj/).
- World rice, maize, and wheat demand increase - approx 300 Mt from 1996-2003 to 2025 (Cassman et al., 2003).
- World grain demand increase faster than world population increase
- Increasing ethanol production may increase corn demand.

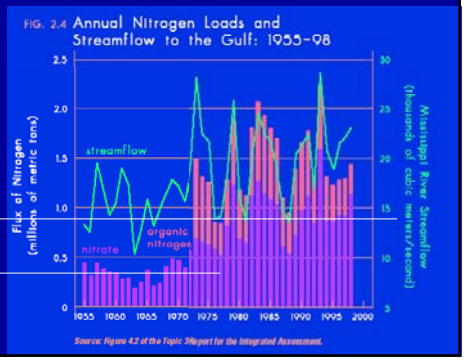
Consequences of N use

Nr enrichment contribute to (Vitousek et al., 1997):

- greenhouse gas production and depletion of stratospheric ozone;
- loss of soil nutrients such as calcium and potassium;
- the acidification of soils, streams, and lakes in several regions;
- increased organic carbon stored within terrestrial ecosystems;
- accelerated losses of biological diversity;
- **hypoxia**

From Rabalais et al. (2006)

Consequences of N use



Problem

"…we view the **dual goals of meeting food demand while protecting the environment** from excess Nr as one of the greatest ecological challenges facing humankind." (Cassman et al., 2002)

Problem

The Executive Director for the Soil and Water Conservation Society stated, "… **quantifying conservation may be among the most important challenges currently confronting the conservation science community**" (Cox, 2002).

Complexity of Problem

Nitrogen leaching and corn yield are dependent upon:

- N application rate
- Soil type
- N application type
- N application timing
- Rainfall
- Temperature
- Previous conditions
- Variable interactions
- Variable exponents (powers)

Question

Can **simple** equations be developed that **accurately** quantify nitrate loss and corn production?

One Solution

Multivariate Polynomial Regression

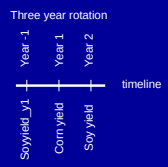
$$Y = a_0 + a_1(v_1) + \ldots + a_x(v_x) +$$

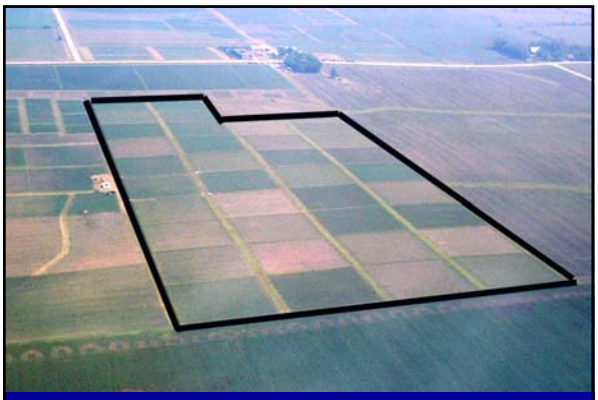
$$a_{12}(v_1 * v_2) + \ldots + a_{yx}(v_y * v_x) +$$

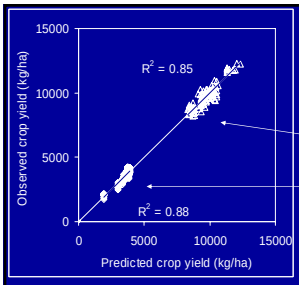
$$a_{11}(v_1)^2 + \ldots + a_{xx}(v_x)^2$$

The Dataset

- Northeastern Iowa Research Station
- 1994-2003
- Corn-soybean rotation
- 36 plots with tile drainage
- N application:
  - Fall manure
  - Early spring manure
  - Early spring UAN
  - Split spring UAN
  - N rates from 75-250 kg/ha





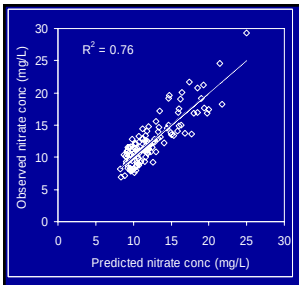


Corn yield =

5318 + 396 * rain_ja – 45*type*rain_ja - 5.8*rain_ja^2

+ 0.003*type*soyyield_y1*Nappli - 0.028*temp_ja*soyyield_y1 + 0.33*temp_ja*Nappli

Soybean yield = f(rain_ja, temp_ja)



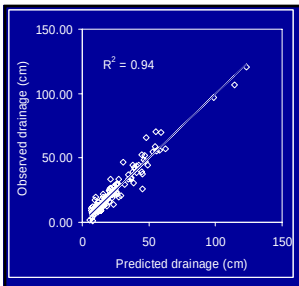
Two-year flow-weighted nitrate concentration from both corn and soybean

Natural log of Nitrate concentration in drainage =

1.46 + 1.9E-04*soyyield_y1 - 1.1E-03*type*soyyield_y1 + 2.2E-07*type*soyyield_y1^2

-7.6E-03*rain_soy + 4.2E-02*rain_corn - 2.4E-04*rain_corn^2

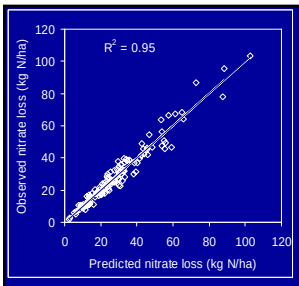
+ 3.7E-03*Nappli - 6.2E-03*Ntime + 4.3E-03*type*Ntime



Two-year drainage amount from both corn and soybean

[Drainage]$^{0.5}$ =

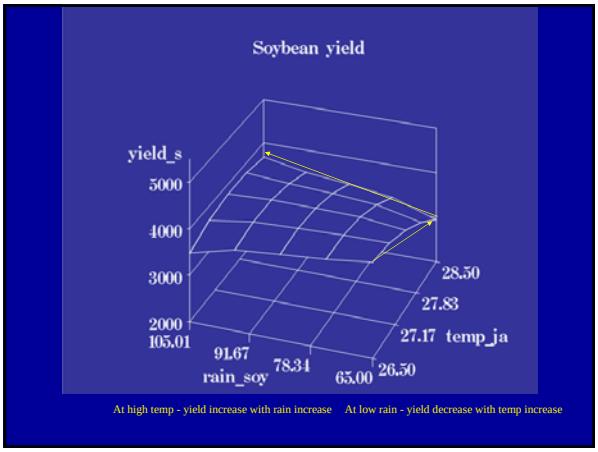
0.033 + 11.0*di + 0.036*di*rainnet_tot - 8.1*di2 + 0.00012*rainnet_tot2



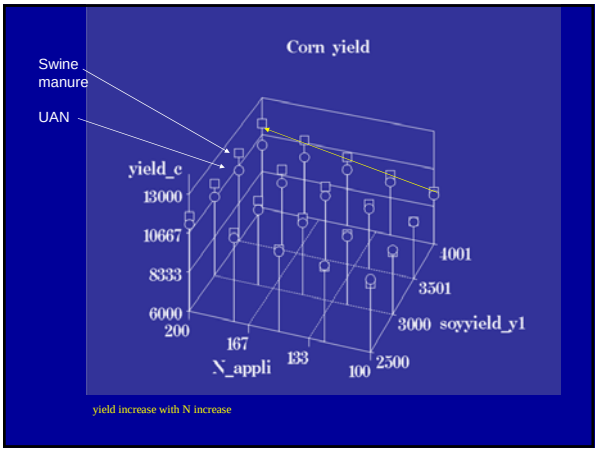
Two-year nitrate loss from both corn and soybean

[Nitrate Loss in drainage]$^{0.5}$ =

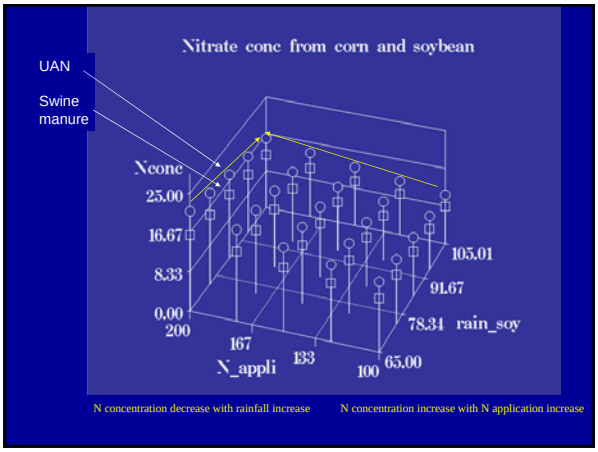
-5.7 +1.4*drain$^{0.5}$ + 2.1*LN(Nconcp) - 0.033*drain



At high temp - yield increase with rain increase At low rain - yield decrease with temp increase



yield increase with N increase



N concentration decrease with rainfall increase N concentration increase with N application increase

Ntime	Nappli (kg/ha)	N type	Corn yield (kg/ha)	Drain (cm)	Nconc (mg/L)	Nload (kg/ha)
Early spring	125	UAN	9741	27	14	36
Early spring	150	UAN	9967	27	15	38
Split spring	125	UAN	9741	27	11	30
Split spring	150	UAN	9967	27	12	32
Late fall	125	s.m.	10038	27	14	37
Late fall	150	s.m.	10527	27	16	39
Early spring	125	s.m.	10038	27	12	29
Early spring	150	s.m.	10527	27	13	31

Problem

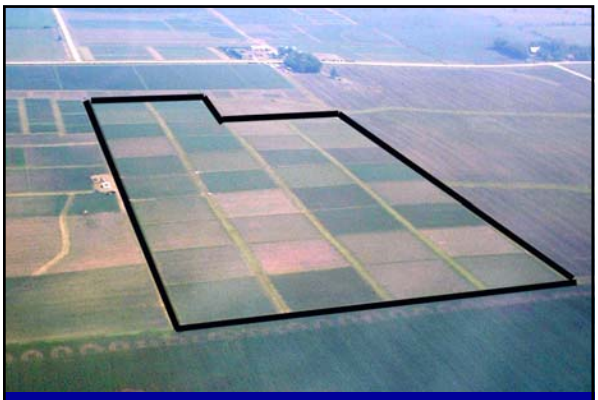
Field experiments and statistical models allow analysis of treatments under very limited conditions

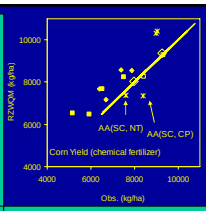
- Soils
- Climates
- Management

Question

Can agricultural system models help fill in knowledge gaps?

- Dr. Dan Jaynes, Soil Scientist, National Soil Tilth Laboratory, USDA-ARS, Ames, IA
- Miss. River Gulf of Mexico Watershed Nutrient Task Force
- N in Miss. + tributaries contribute to hypoxia
- Ag Mgmt that reduces N in tiles + maintain adequate grain production
- Ag. Systems models tool to optimize ag mgmt systems





N type [1]	N rate [2] (kg N/ha)	N mgmt. [3]	drain (cm)	NO3-N loss (kg N/ha)	corn yield (kg/ha)	f.w. NO3-N conc [4] (mg/L)
UAN	100	preplant	11.3	10.1	7790	8.9
UAN	125	preplant	11.3	12.1	8178	10.7
UAN	150	preplant	11.4	14.3	8428	12.6
UAN	175	preplant	11.4	16.7	8636	14.6
UAN	200	preplant	11.4	19.2	8754	16.8
UAN	150	fall	11.3	17.2	8123	15.3
AA	150	fall	11.3	16.7	8367	14.7
AA	150	preplant	11.4	14.7	8387	12.9
UAN	100	split	11.3	10.3	7843	9.1
UAN	125	split	11.3	12.3	8144	10.9
UAN	150	split	11.4	14.6	8408	12.8
UAN	175	split	11.4	16.9	8593	14.9
UAN	200	split	11.4	19.5	8755	17.1
UAN	144	LSNT	11.3	14.2	8248	12.5
SM	150	preplant	11.4	14.5	8432	12.7
SM	150/150	preplant	11.3	22.8	8581	20.1
SM	150/75	preplant	11.3	17.3	8501	15.2
SM	150	fall	11.3	16.5	8310	14.5
SM	150/150	fall	11.2	35.6	8314	31.8
SM	150/75	fall	11.3	26.1	8278	23.1
UAN	150	pre_cover	10.7	9.5	8292	8.9
SM	150/150	pre_cover	10.6	17.3	8494	16.3

Summary and Conclusions

- Empirical equations can be developed based on field data.
- Field data is limited.
- RZWQM accurately responded to conditions.
- But process based models are difficult to use
- Can models be used to populate a database???