Empirical Modeling of Nitrate Loading and Crop Yield for Corn-Soybean Rotations in Iowa

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USDA United States Department of Agriculture

ars Agricultural Research Service

National Soil Tilth Laboratory Creating Agricultural Success

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).

Problem

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

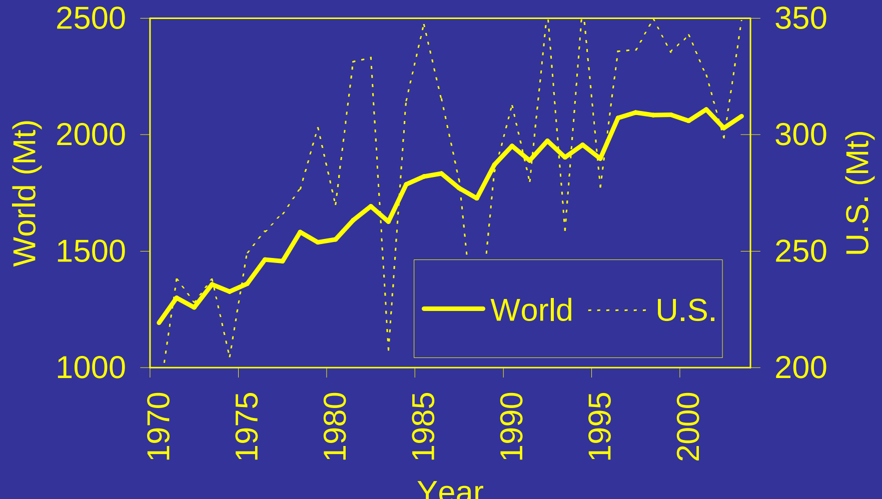
Problem

"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).

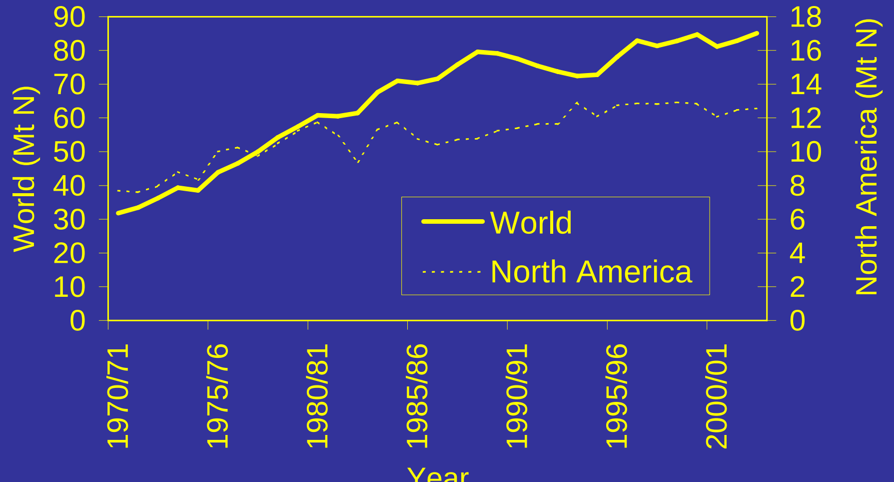
Problem

Total cereal production (Mt)



(source: http://faostat.fao.org/)

Nitrogen fertilizer-N consumption (Mt N)



(source: http://www.fertilizer.org/ifa/)

N in the environment

FIG. 2.3 Long-term Records of Changes in the Mississippi-Atchafalaya River Basin: 1900-99

Sources: Figure 5.7 of the Topic 3 Report for the Integrated Assessemnt; and Figure 1.2 of the Topic 5 Report.

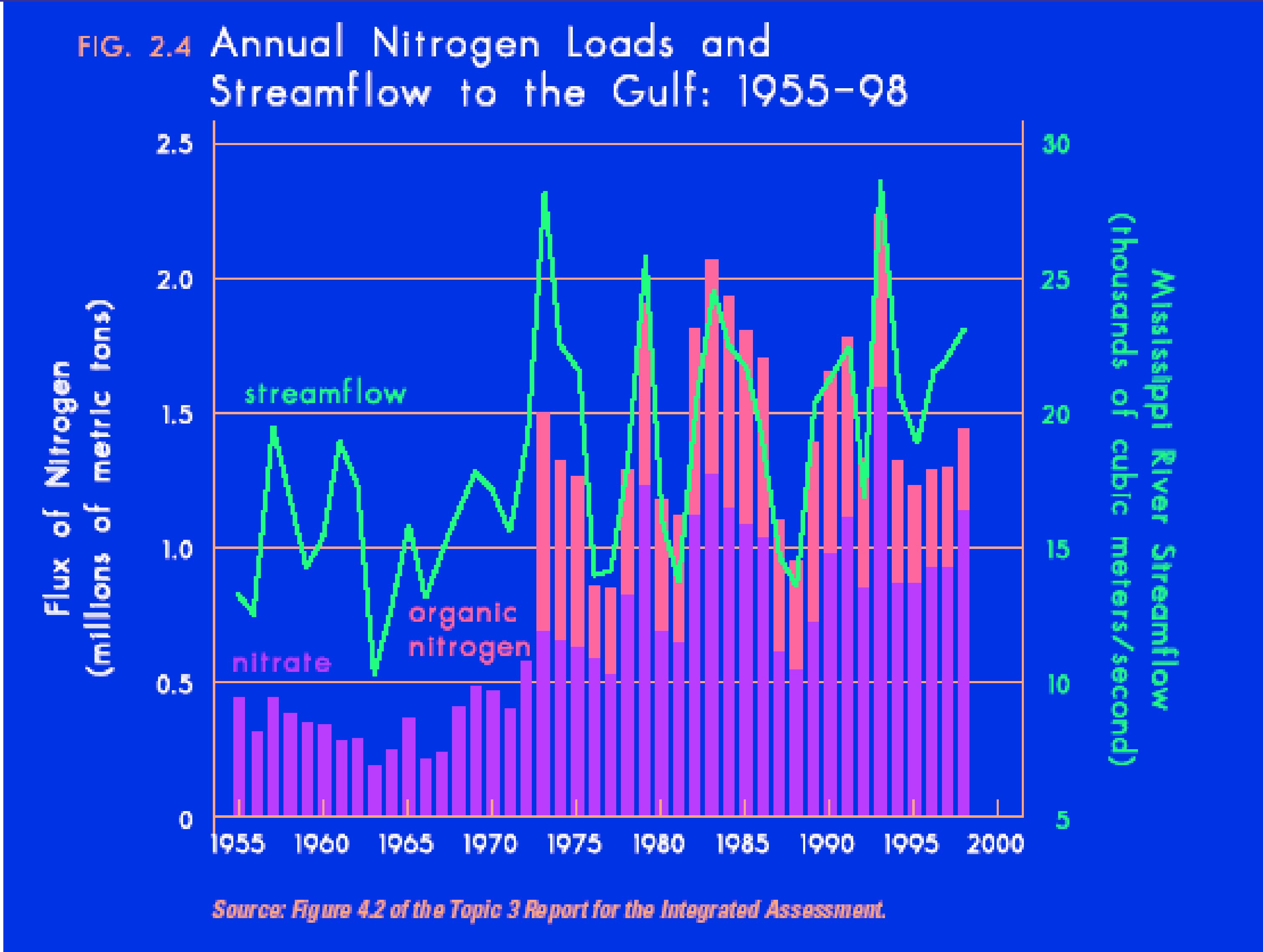
The amount of nitrogen fertilizer used in the Basin increased dramatically between the 1950s and 1980s (enabling a large increase in crop production). The area of cropland fitted with artificial subsurface drains has also increased, reducing the capacity of the landscape to remove nitrogen.

Source:

CENR. 2000. Integrated Assessment of Hypoxia in the Northern Gulf of Mexico. National Science and Technology Council Committee on Environment and Natural Resources, Washington, DC. Available at http://www.nos.noaa.gov/products/hypox_final.pdf

N in the environment

Source:
CENR 2000



The annual flux of nitrate nitrogen from the Basin to the Gulf of Mexico has almost tripled between the periods 1955-70 and 1980-96. Organic nitrogen measurements were not regularly made before 1973 but show no trend. Both streamflow and nitrate flux have become much more variable in the last 25 years.

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

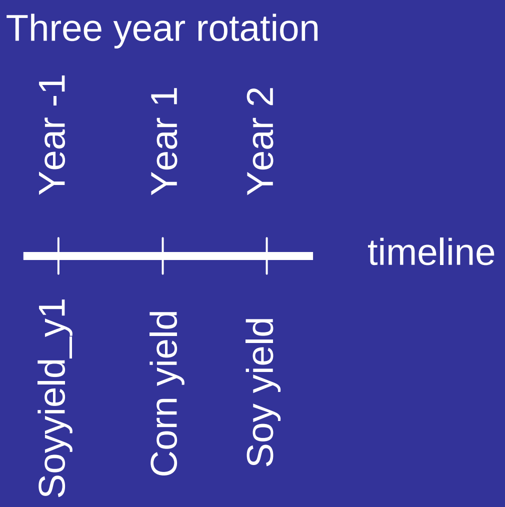
$$Y = a_0 + a_1(v_1) + \ldots + a_x(v_x) +$$

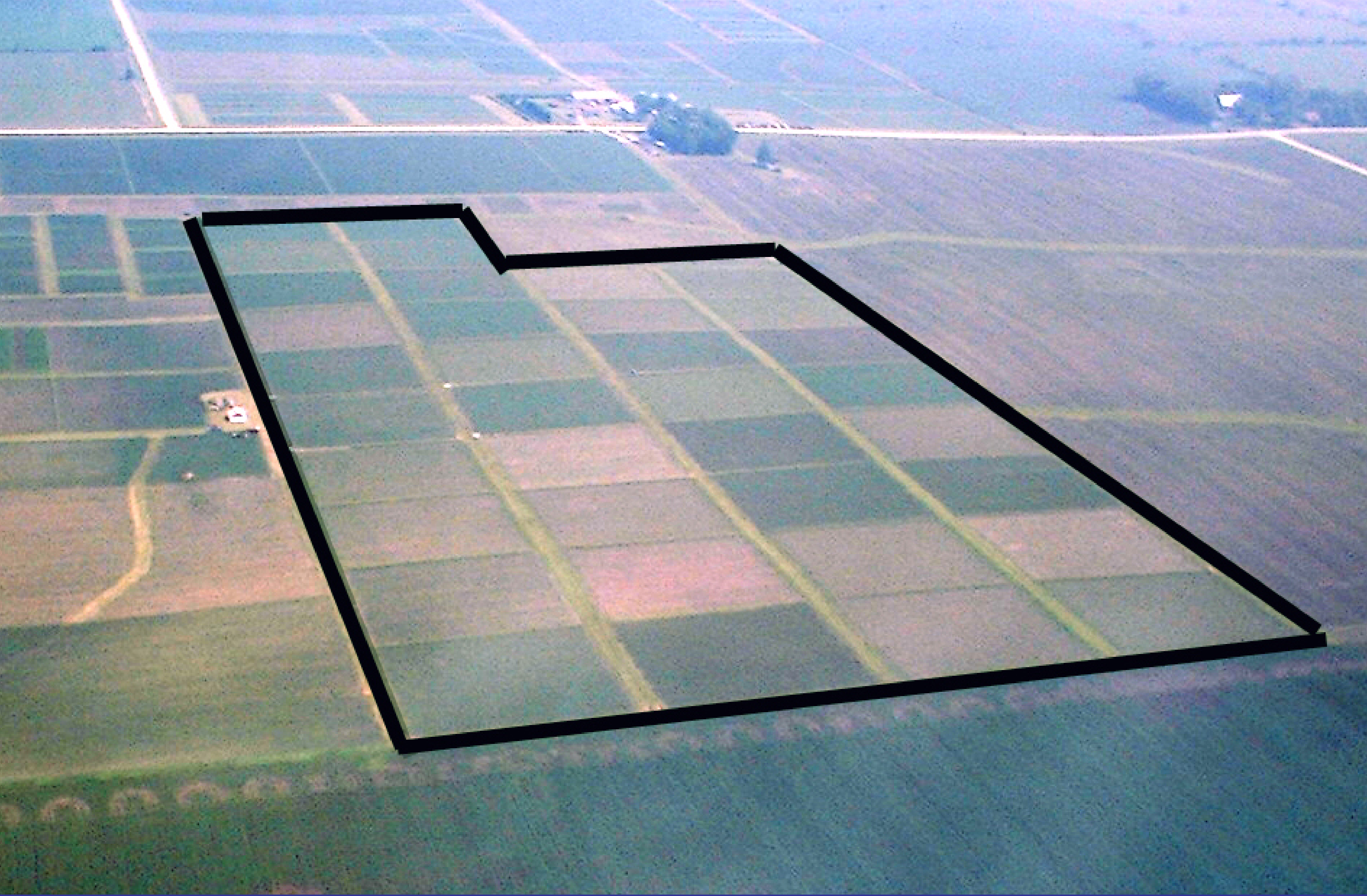
$$a_{12}(v_1 * v_2) + \ldots + a_{yx}(v_y * v_x) +$$

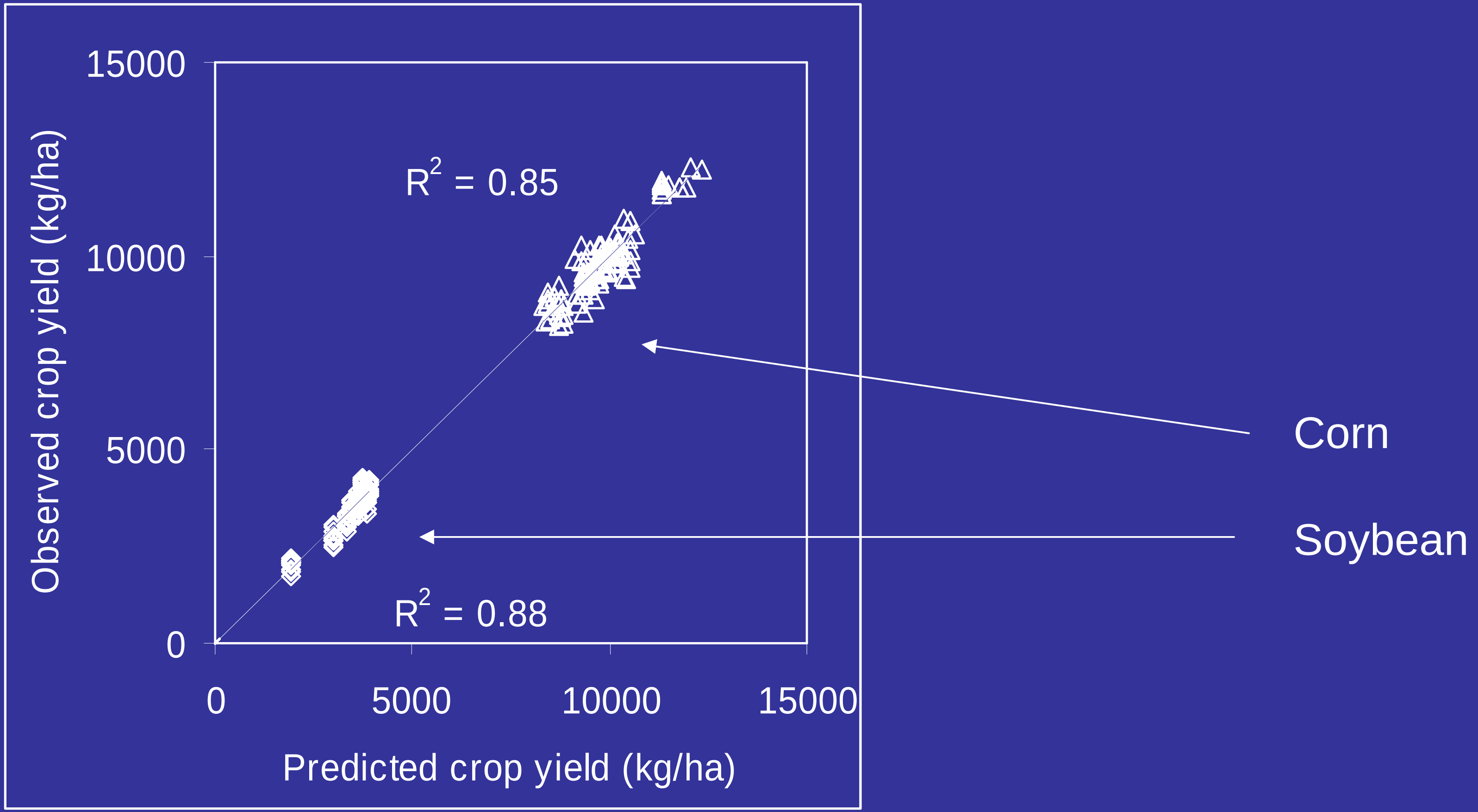
$$a_{11}(v_1)^2 + \ldots + a_{xx}(v_x)^2$$

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





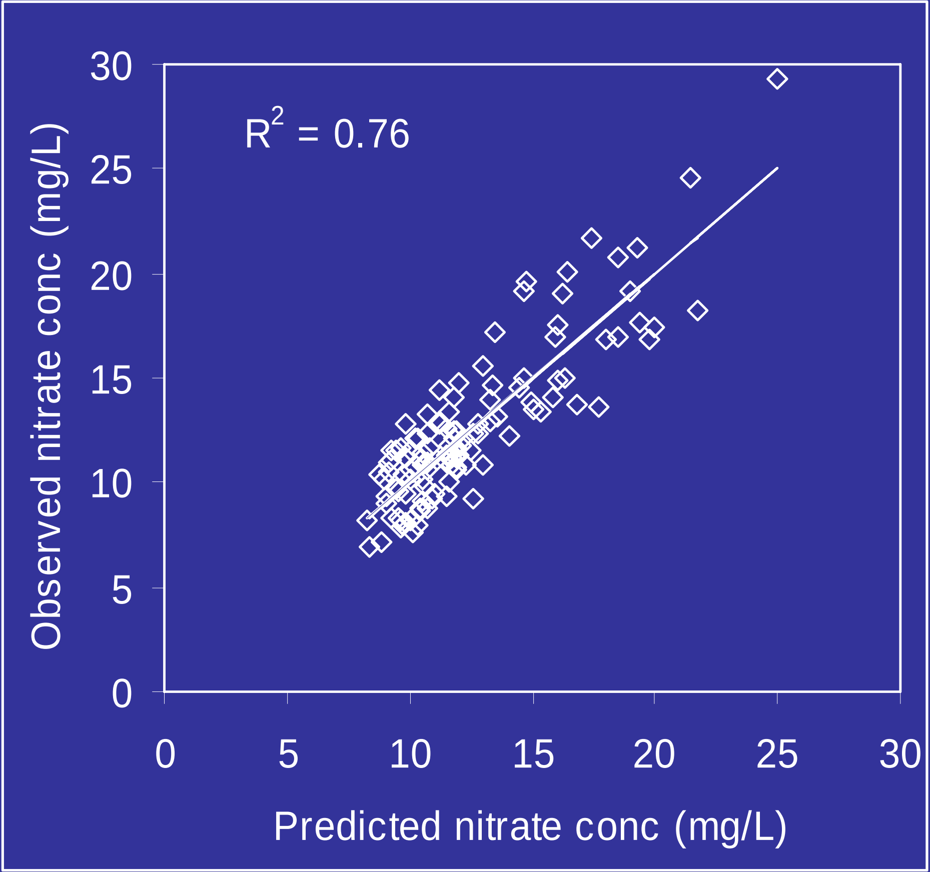


Corn yield =

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)



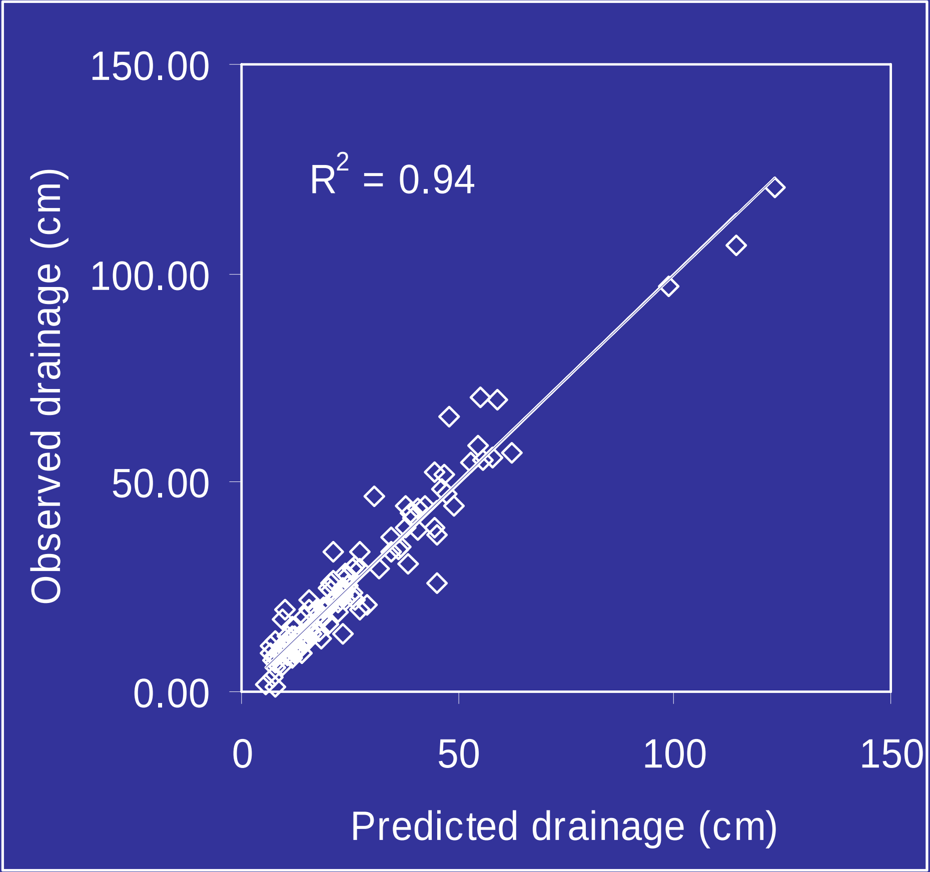
Two-year flow-weighted nitrate concentration from both corn and soybean

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

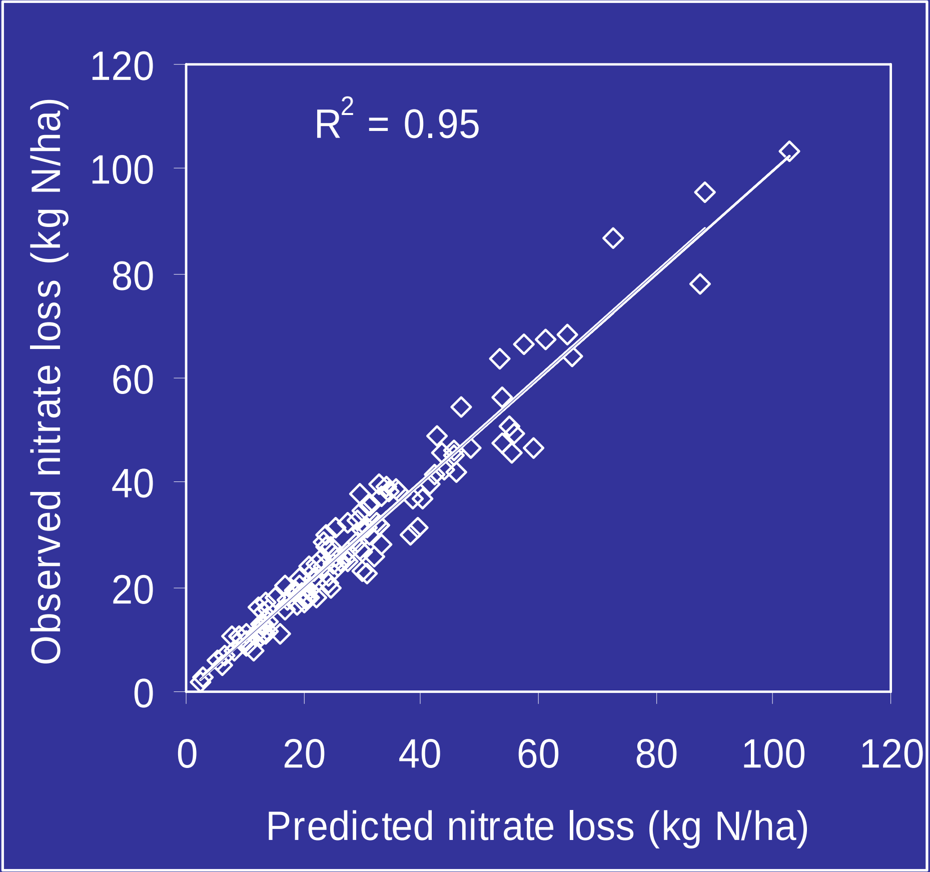
+ 3.7E-03*Nappli - 6.2E-03*Ntime + 4.3E-03*type*Ntime



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

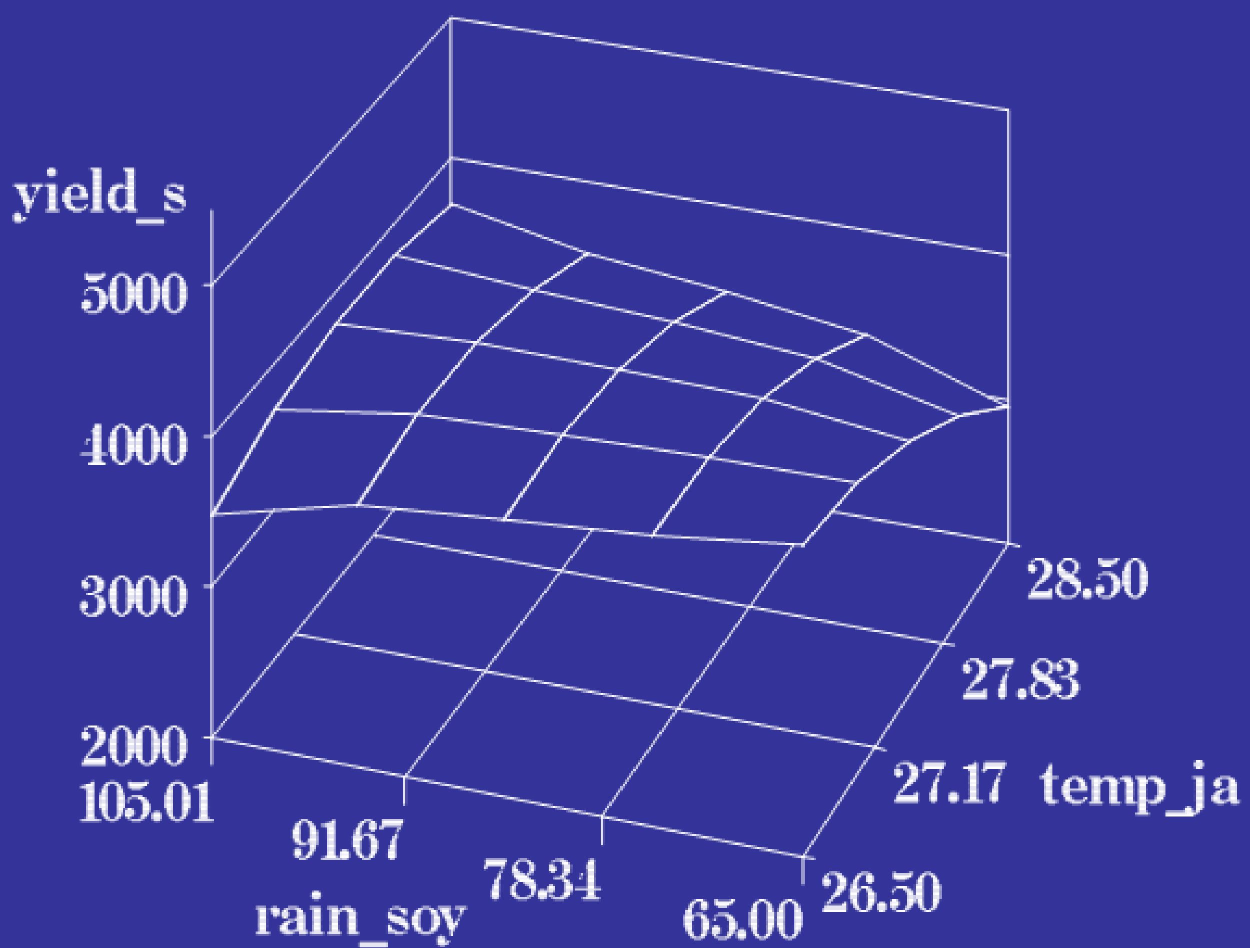


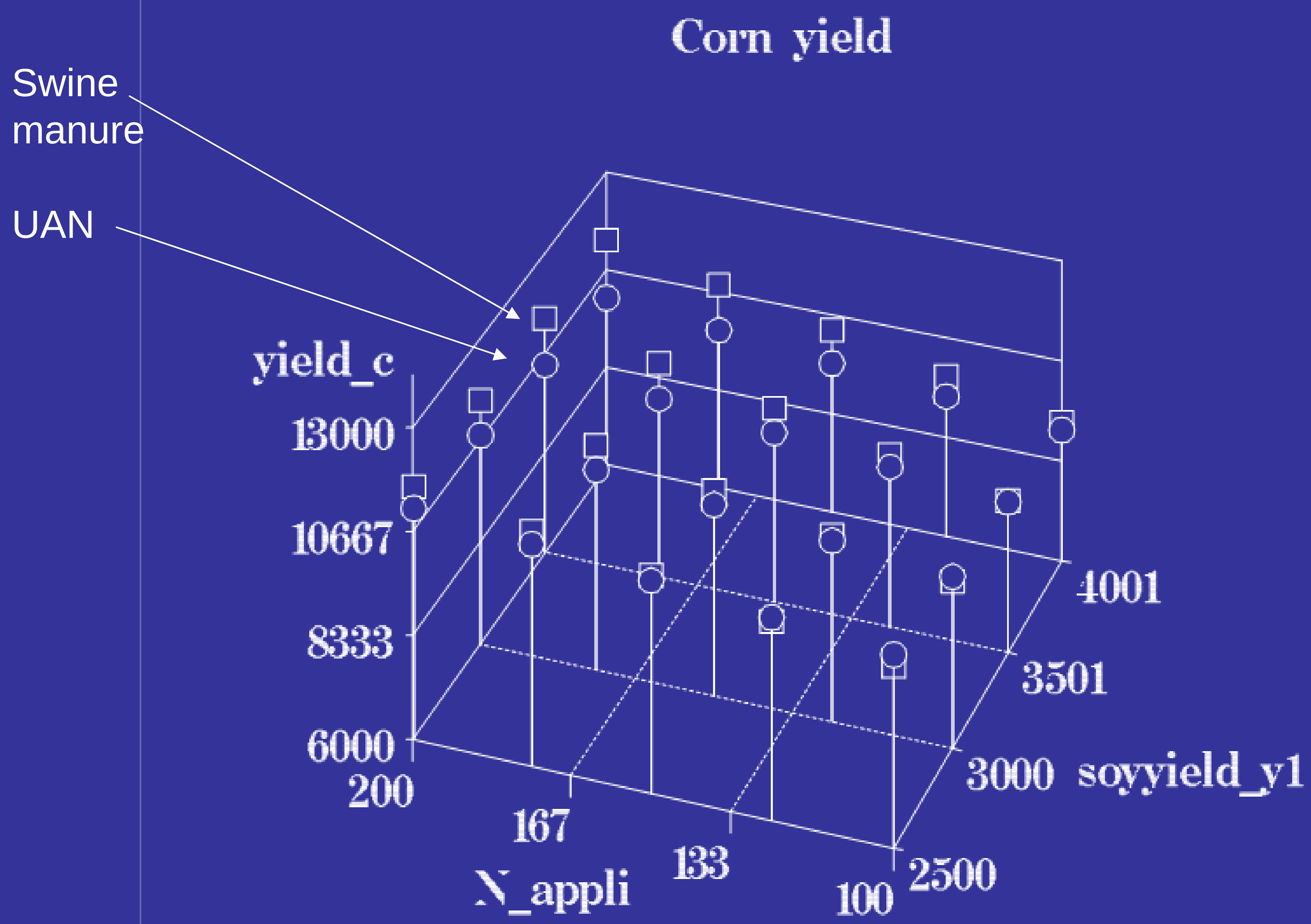
Two-year nitrate loss from both corn and soybean

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

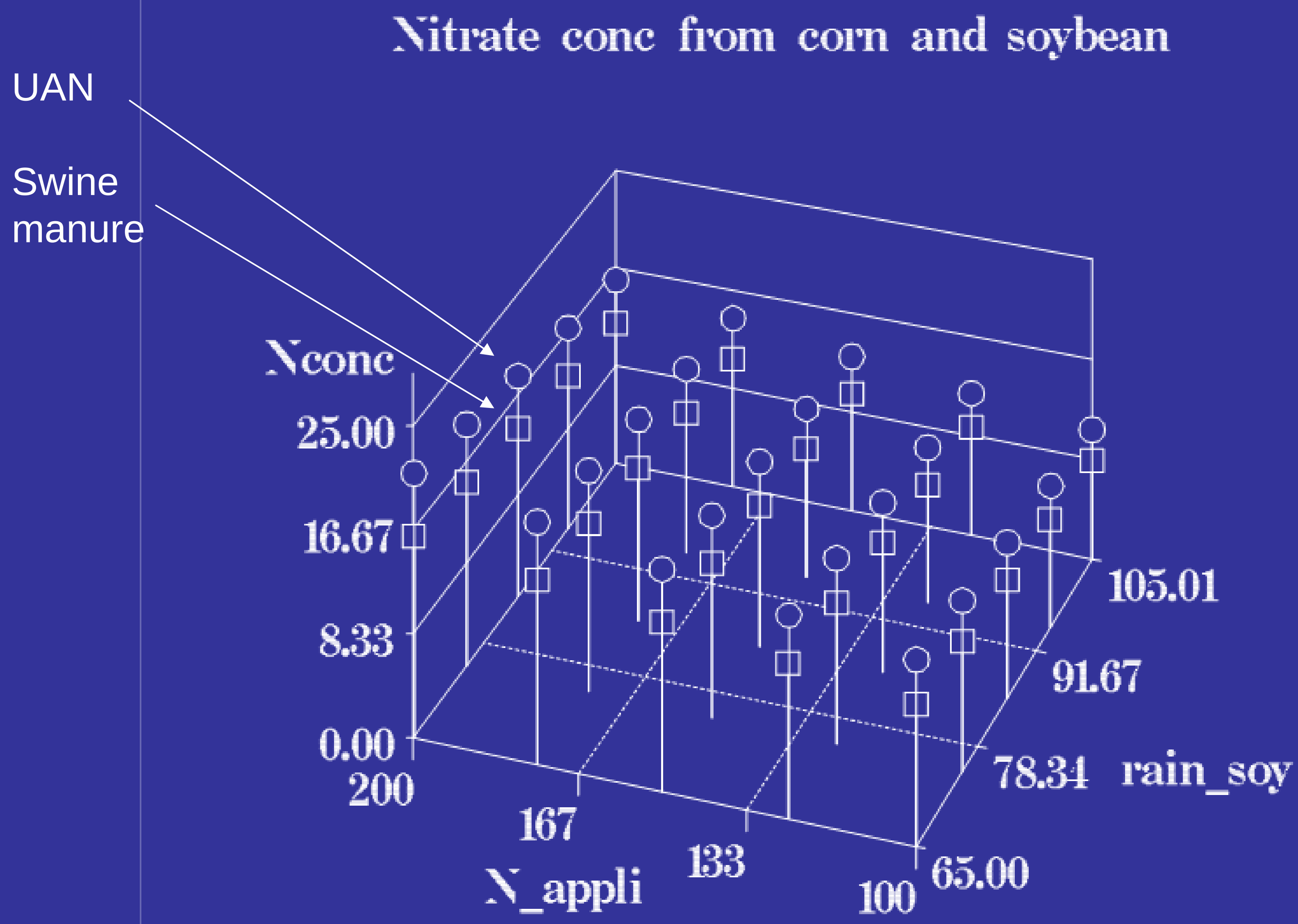
$$-5.7 + 1.4 * \text{drain}^{0.5} + 2.1 * \text{LN(Nconcp)} - 0.033 * \text{drain}$$

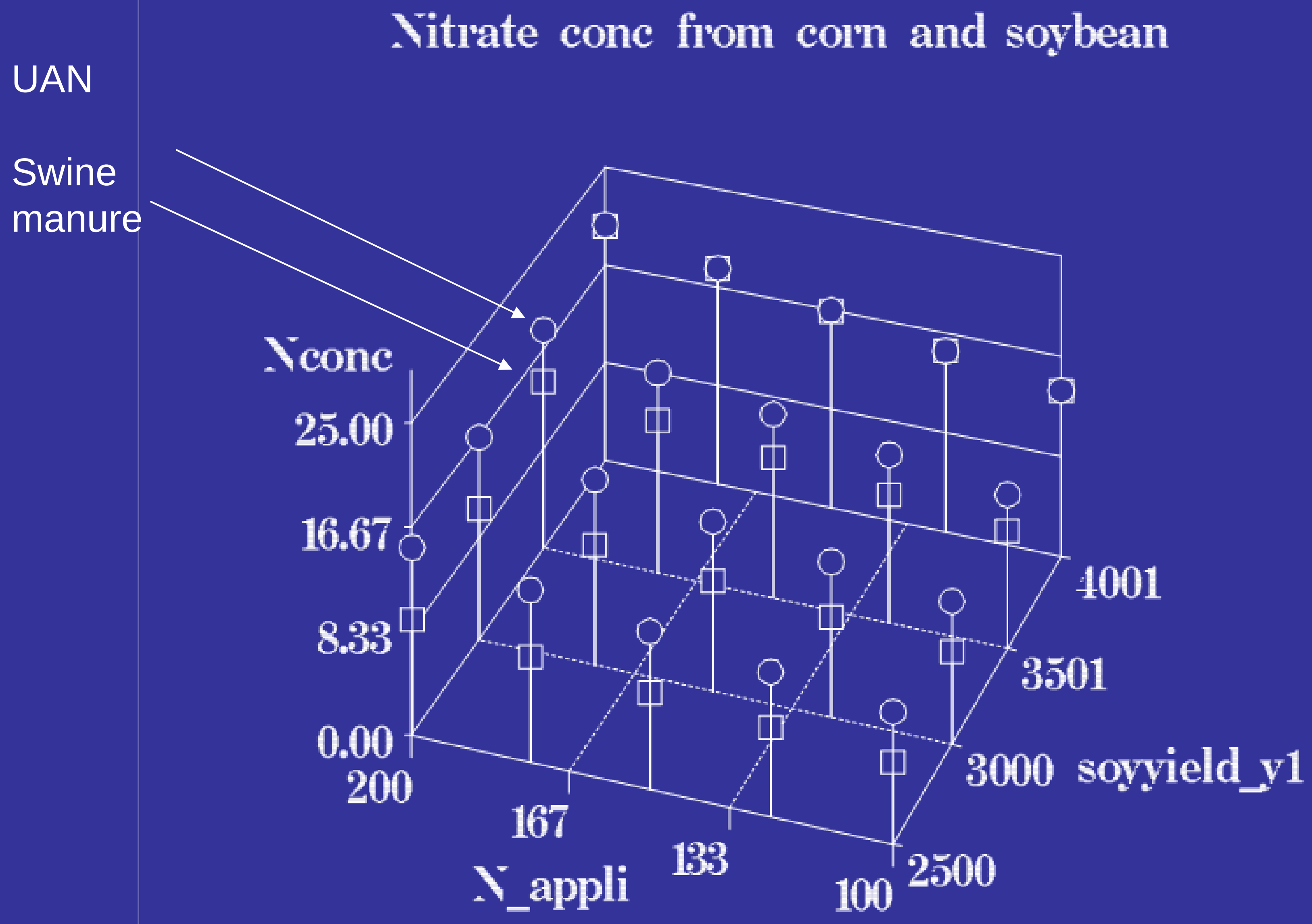
Soybean yield





Swine manure
UAN
Corn yield
yield_c
13000
10667
8333
6000
200
167
133
100
N_appli
4001
3501
3000
2500
soyyield_y1


Nitrate conc from corn and soybean
UAN
Swine
manure
Nconc
25.00
16.67
8.33
0.00
200
167
133
100
N_appli
105.01
91.67
78.34
65.00
rain_soy


Nitrate conc from corn and soybean
UAN
Swine
manure
Nconc
25.00
16.67
8.33
0.00
200
167
133
100
N_appli
4001
3501
3000
2500
soyyield_y1

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

Conclusion

- **Simple** and **accurate** equations were developed!
- More general equations can be developed!