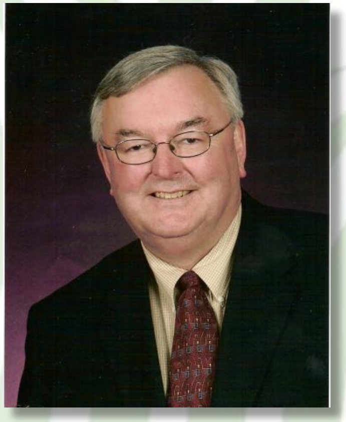
INTERNATIONAL PLANT NUTRITION INSTITUTE

FAR INTO THE FUTURE
FOUNDATION FOR AGRONOMIC RESEARCH

Reaching the 300 bu/A Corn Yield Threshold

What Have We Done?

What Do We Need To Do?



Dr. Harold F. Reetz
International Plant Nutrition Institute
Monticello, Illinois

Thank you!

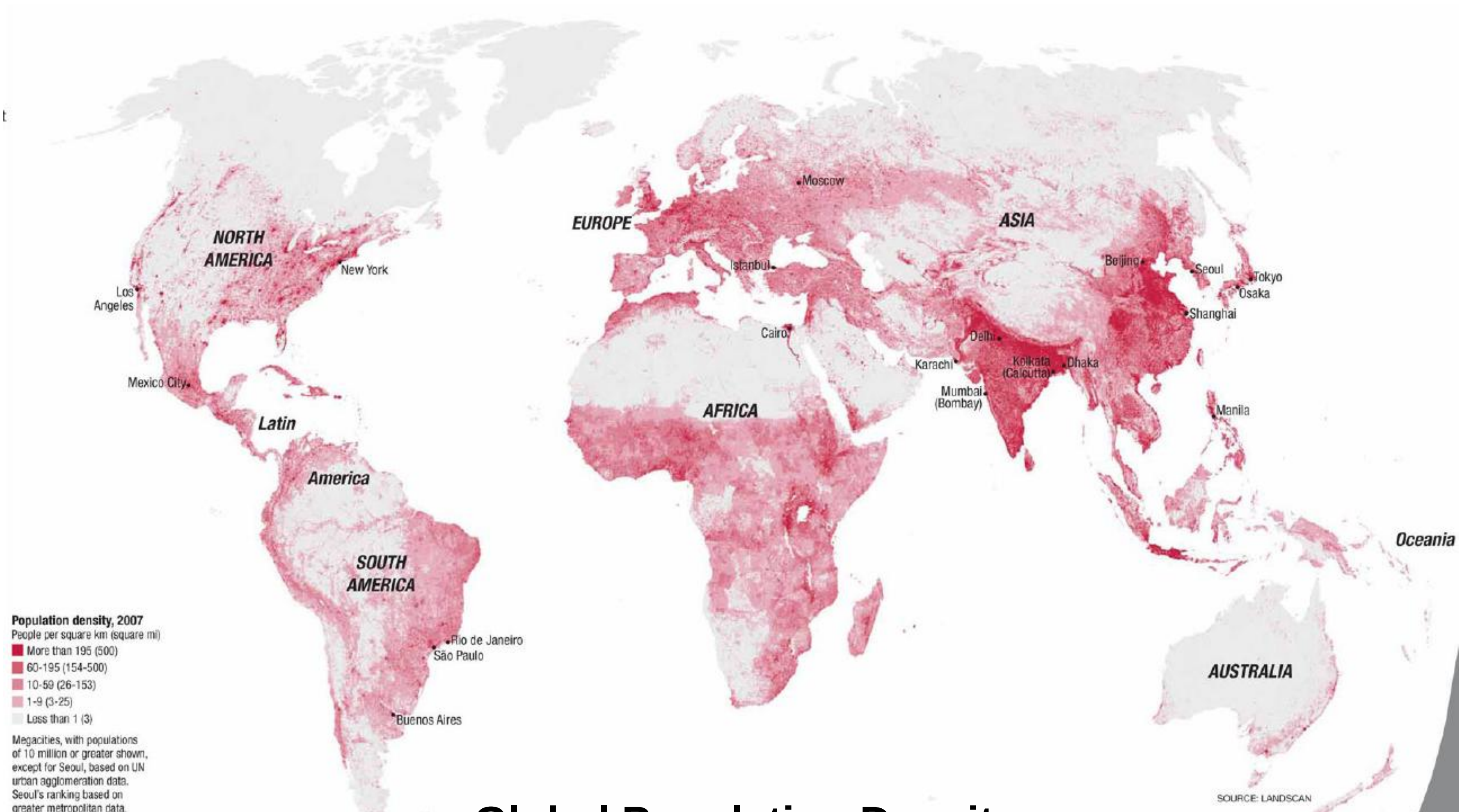
- For the 2009 Fluid Fellow Award

High Yield Corn Production:

Where have we been, what have we learned, where are we going, what do we need to know ???

- 1970s --- Presentation to NFSA on High Yield Corn Production
- 2010 --- Presentation to FFF Fluid Forum on High Yield Corn Production

Growing Population Means Growing Need for Food, Feed, Fiber, and Fuel from Crop Production



Global Population Density **(2007)**

The High Yield Management Concepts Fit Small Farms…

In some cases, each field may be a management zone.

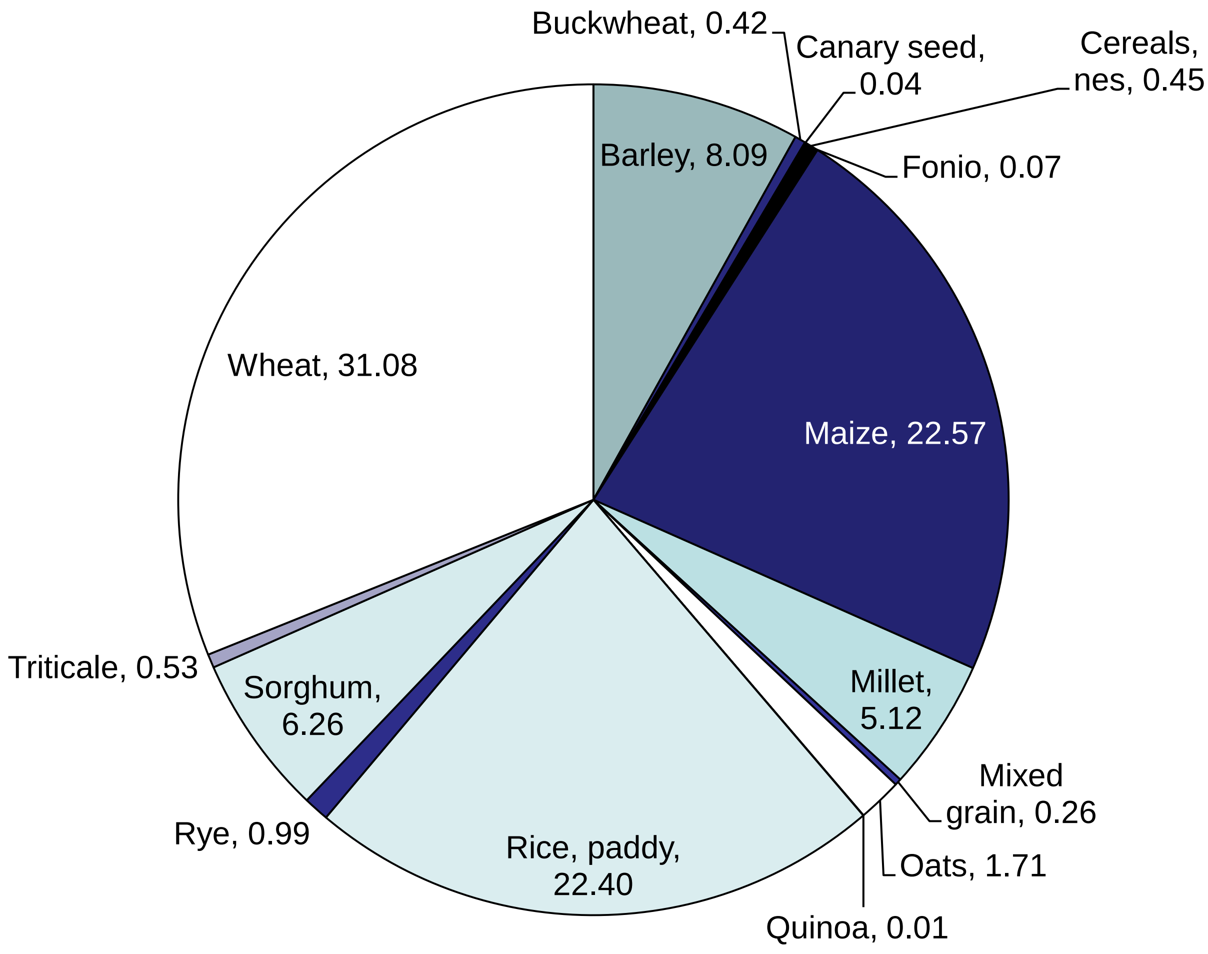
….or Large Farms…

The tools used may be different, but the site-specific management concept still fits.

Land availability is most often the primary limiting resource

The most productive land is already being used. Higher yields improve efficiency

Percent of total global harvested cereal area attributable to each crop: 2007



FAO, 2008

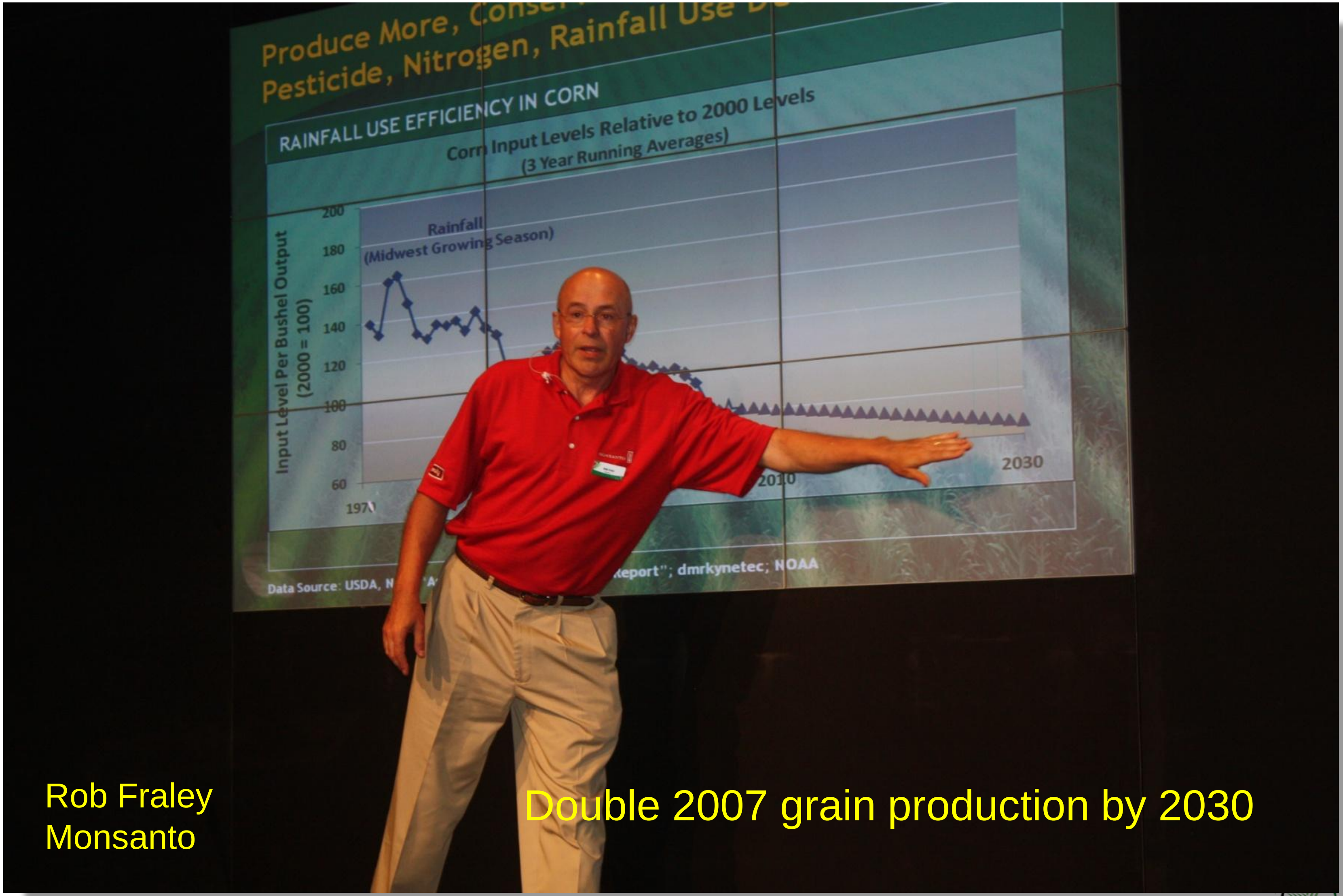
Our Task:

To use emerging technology combined with proven science to continue to feed a growing world population

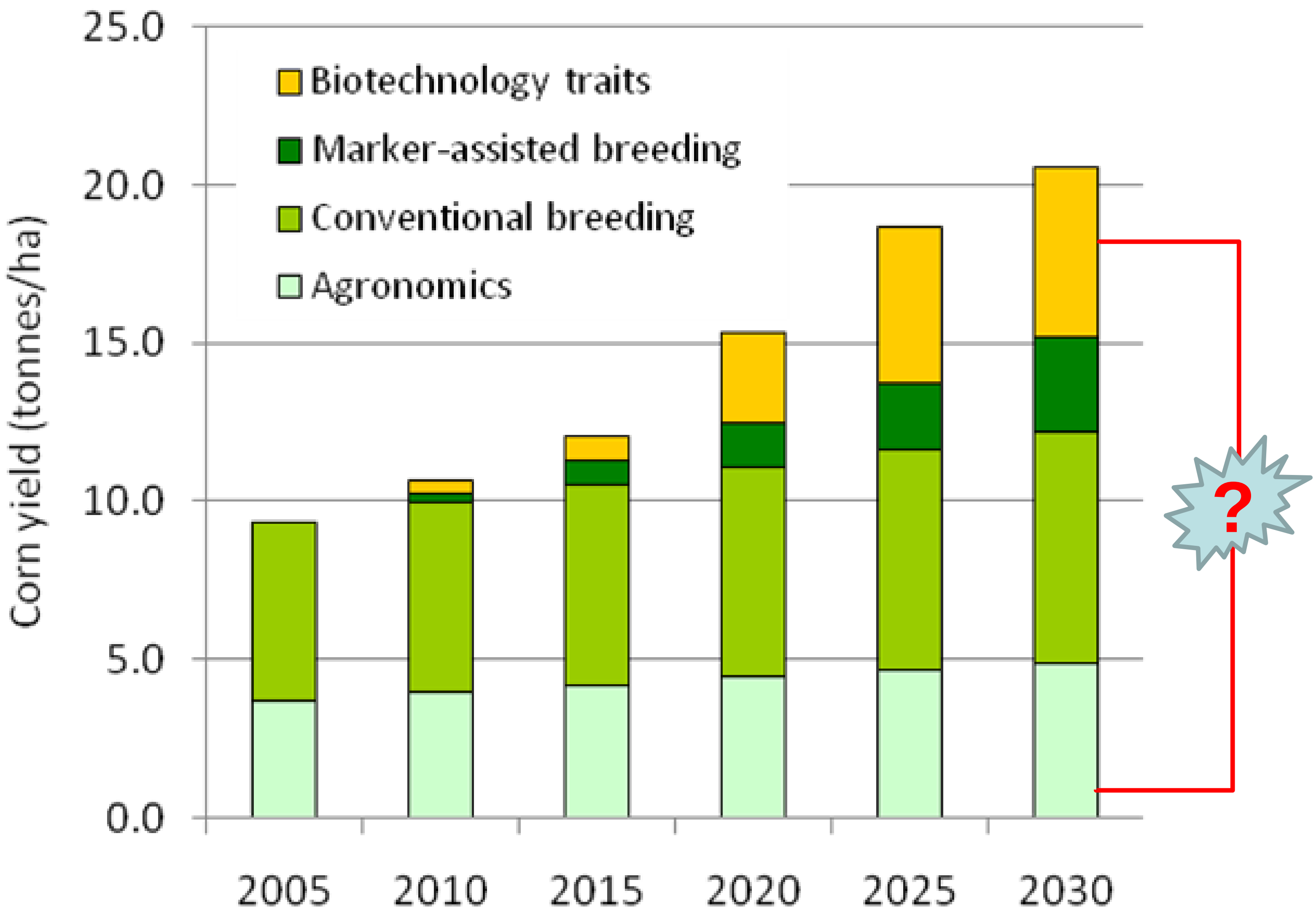
Our Approach:

Grow more yield per unit of land and do it at a higher profit by lowering unit production costs

The Global Production Challenge



Sources of Increased Yield Potential



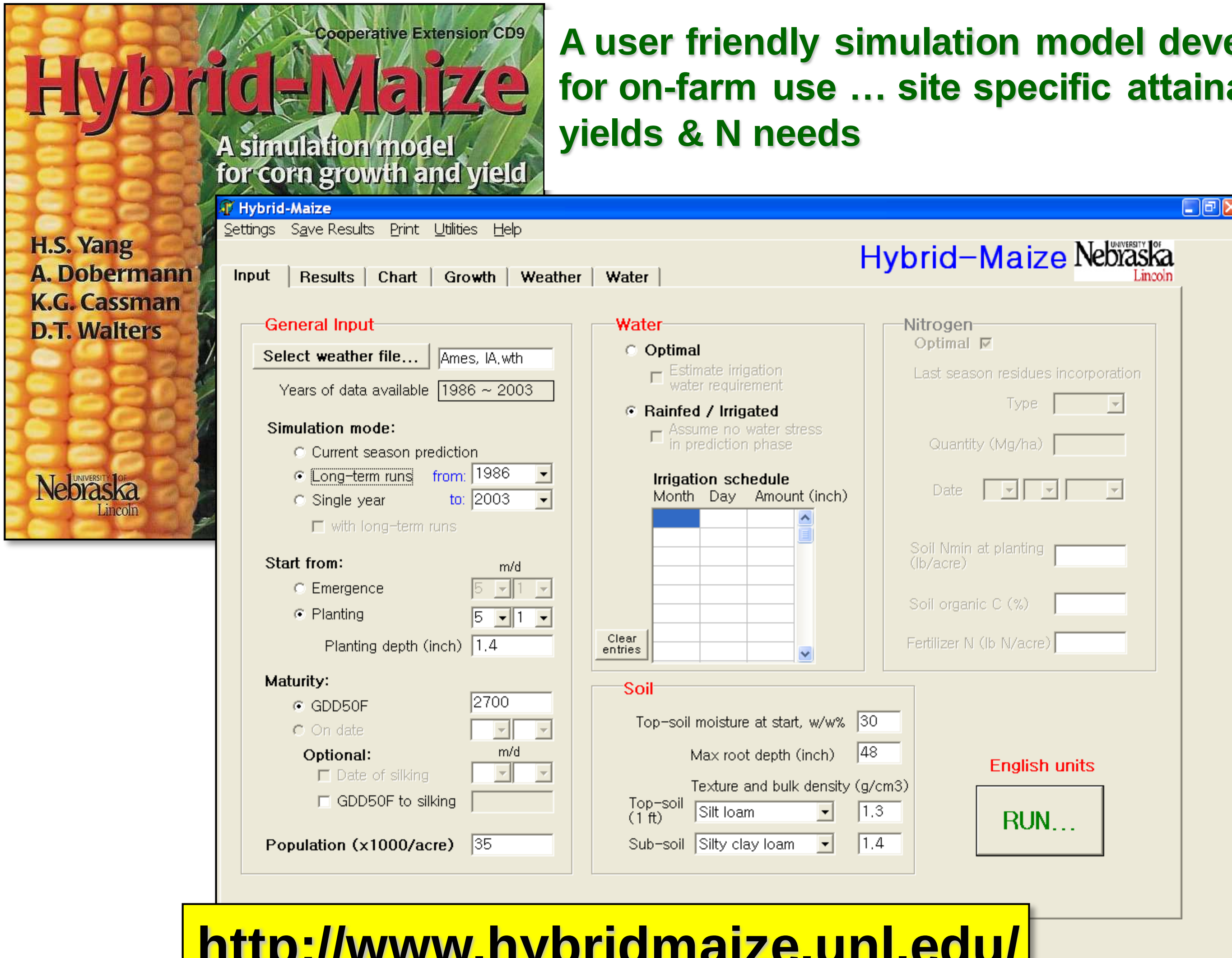
Edgerton, M. D. 2009. *"Increasing Crop Productivity to Meet Global Needs for Feed, Food, and Fuel".* Plant Physiology:149, pp. 7-13.

Potential yield - Realized Yield =

- Profit opportunity for farmers
- Food for another 2.5 billion people
- Relief for the environment
  - more land for buffer strips and wetlands
  - more land for rainforests and recreation
  - high nutrient use efficiency
- Growth opportunity for agribusiness and rural communities

IPNI

Hybrid-Maize Model



A user friendly simulation model developed for on-farm use … site specific attainable yields & N needs

http://www.hybridmaize.unl.edu/

IPNI PNI

The Situation has Changed

- Goal has increased – raising the bar – new challenges
- New tools
  - New genetics
  - New products
  - New equipment
  - New data

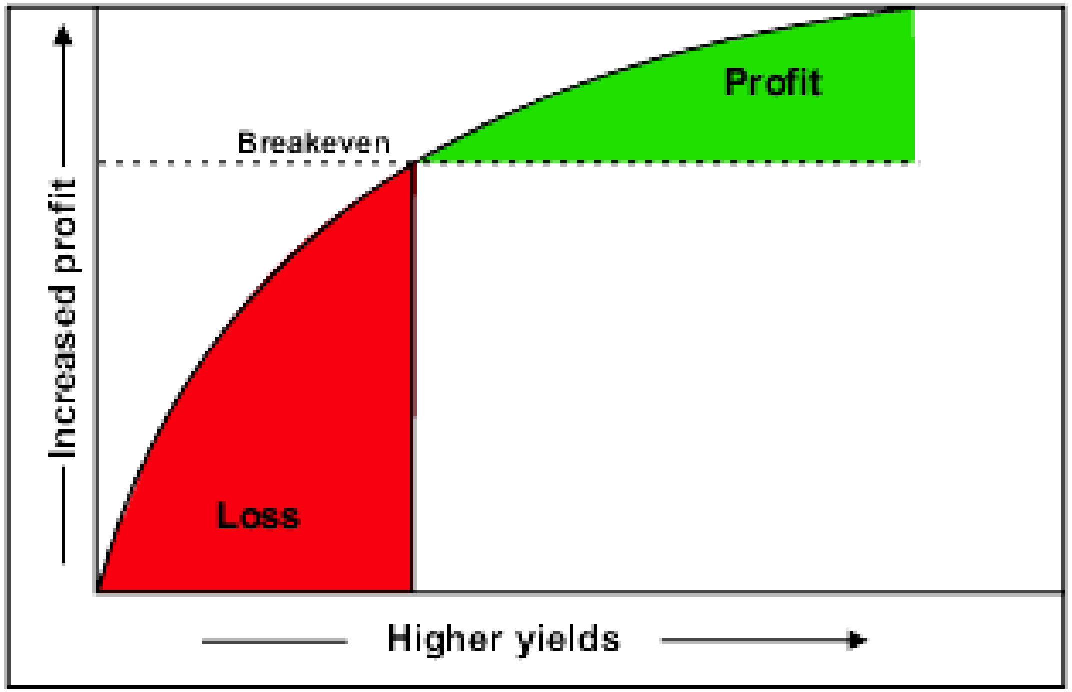
Ultimate Goal: Maximize Profit

FAR
INTO THE FUTURE
FOUNDATION FOR AGRONOMIC RESEARCH

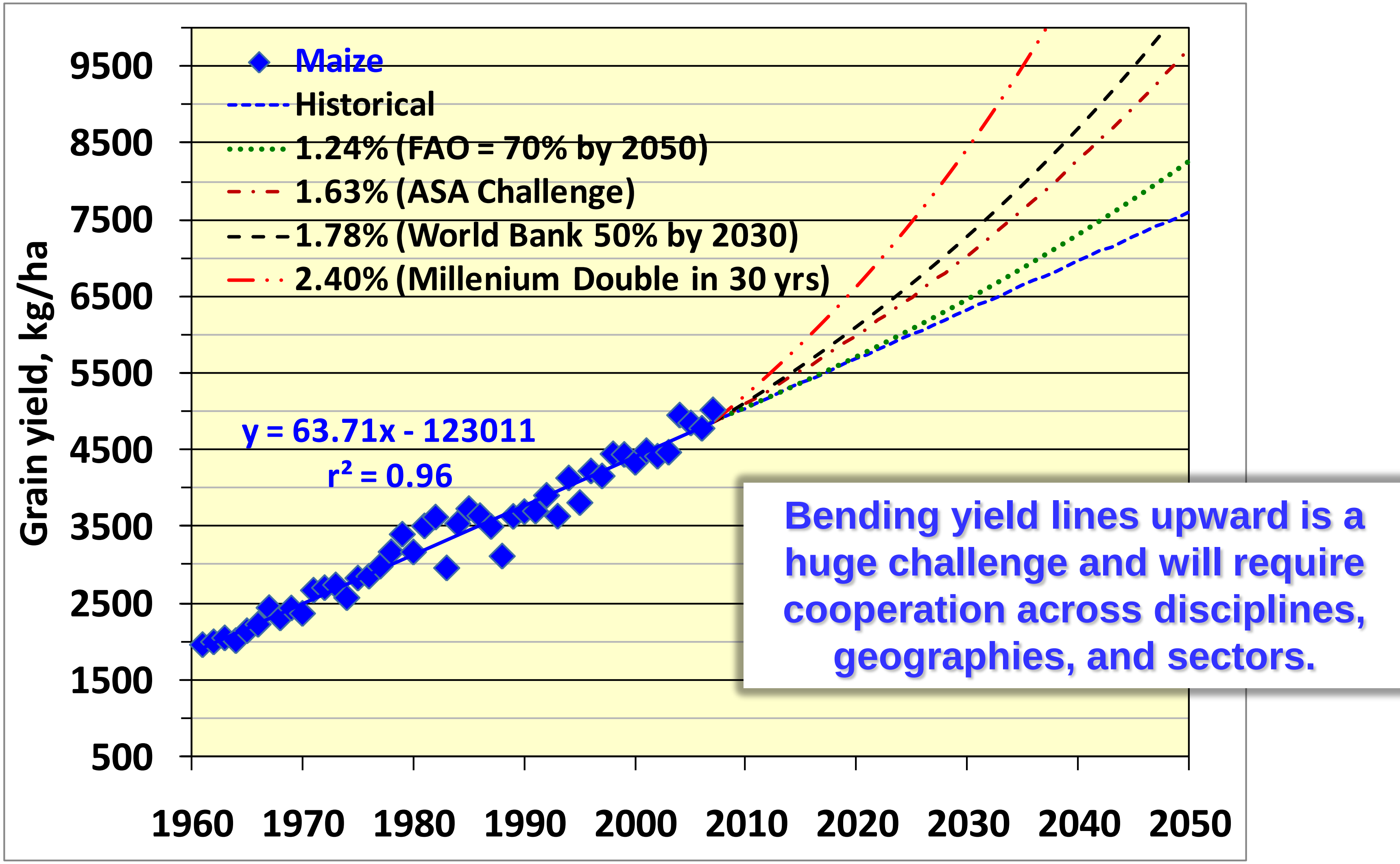
IPNI

Goal: Maximum Corn Profit

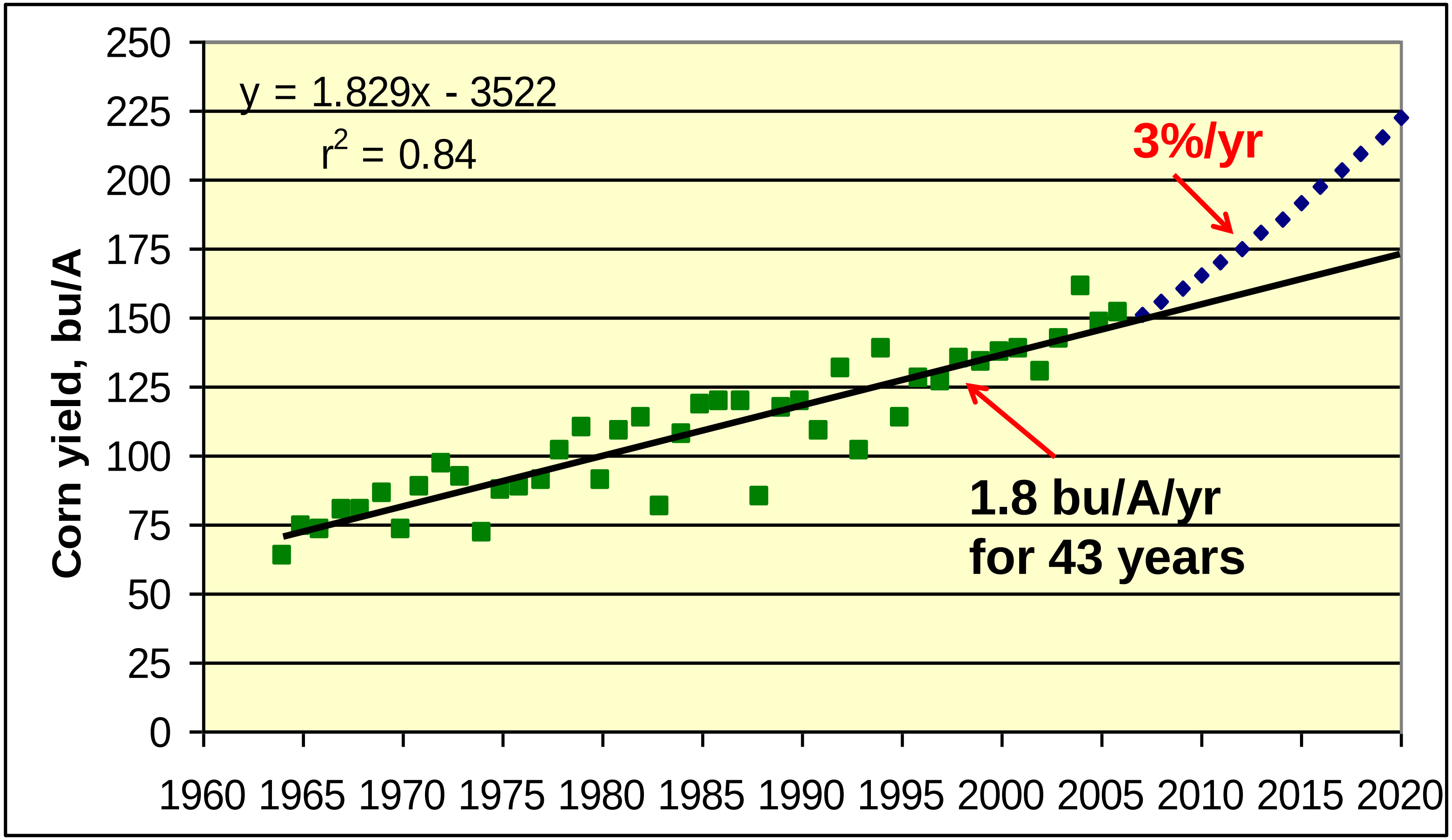
- Profit = Production value – Input costs



Projections of world maize yields



U. S. Corn Yield Trend & Need



Breaking the 1.8 barrier will require our
best agronomic science + **best agronomic management**

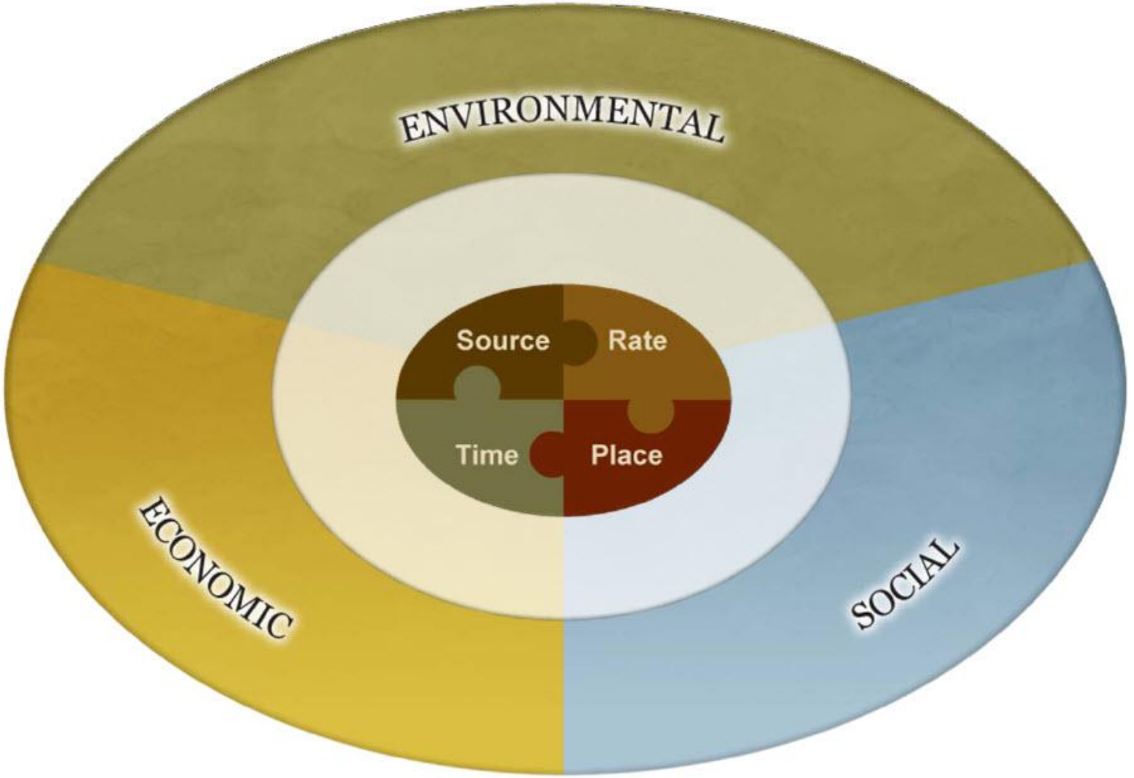
Field Scale to Global Scale
---*One Field at a Time*

- ***Site-specific management applied at the local scale throughout the world creates aggregated benefits at the global scale.***
- As more farmers adopt better practices through site-specific management and ***better-informed decision-making on each field***, the larger-scale results can be realized for *agriculture* and *society* in general, **locally** and **globally**.

"Right" Nutrient Management

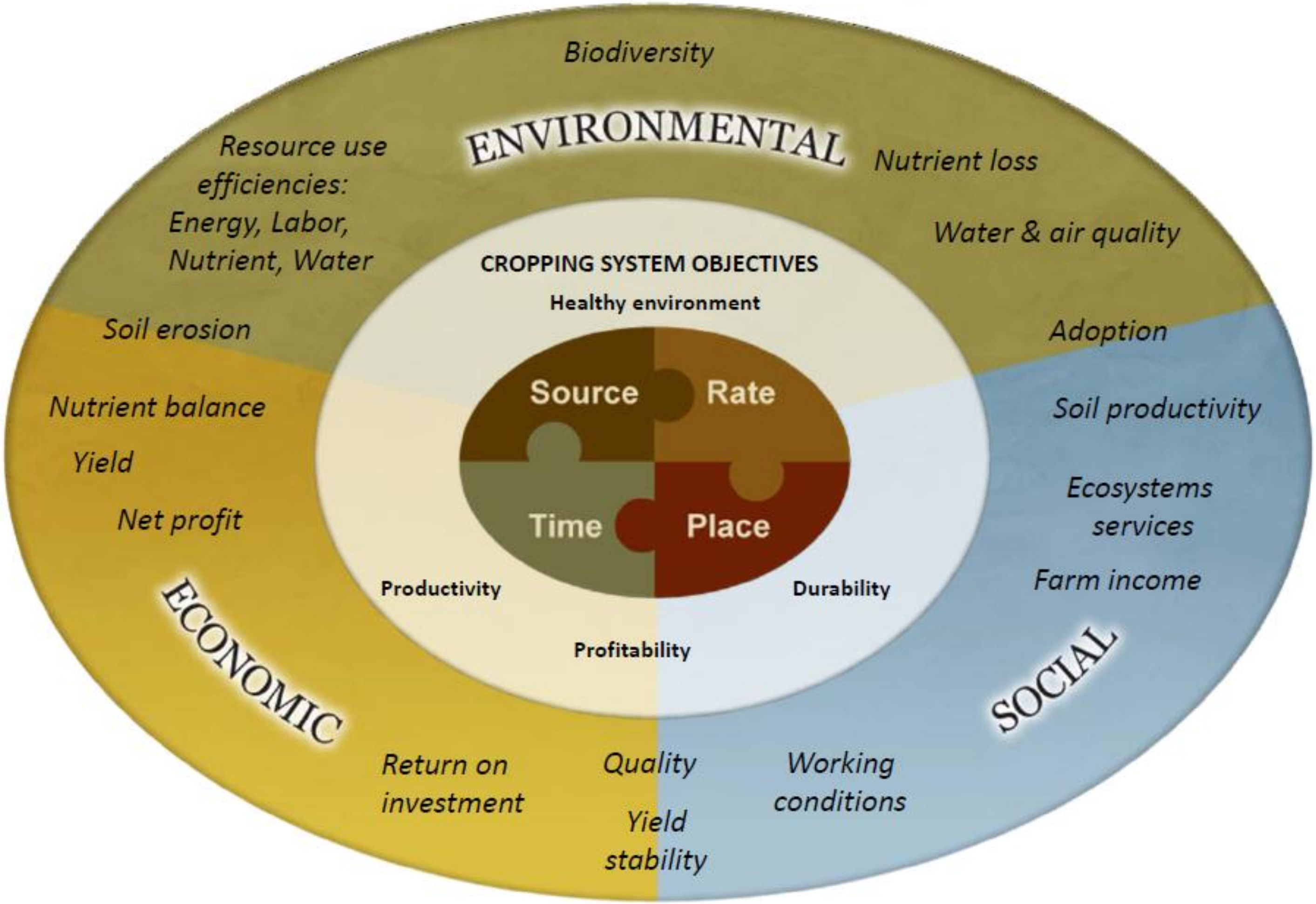
Precision farming …and the various component technologies of precision farming…are essential to "Right" management…to *the* ***4R System for Fertilizer BMPs***.

Right Source
Right Rate
Right Place
Right Time



The Global Framework for 4R Nutrient Management---

---with *Performance Indicators*



See www.ipni.net for more information

Right Source

- **Ensure a balanced supply of ALL essential nutrients, considering soil-supplied, commercial fertilizer, and manure sources, and considering characteristics of specific products, to meet daily plant needs throughout the growing season.**
- **Tools**
  - **Regular scouting of fields to monitor for deficiencies**
  - **Plant analysis in-season to check plant nutrient status**
  - **Modeling of crop growth and nutrient needs**
  - **Placement choices may affect best source choice**
  - **Slow-release fertilizer products; additives**
    - ***ESN, Agrotain, N-Serve, Nutri-Sphere, etc.***

IPNI

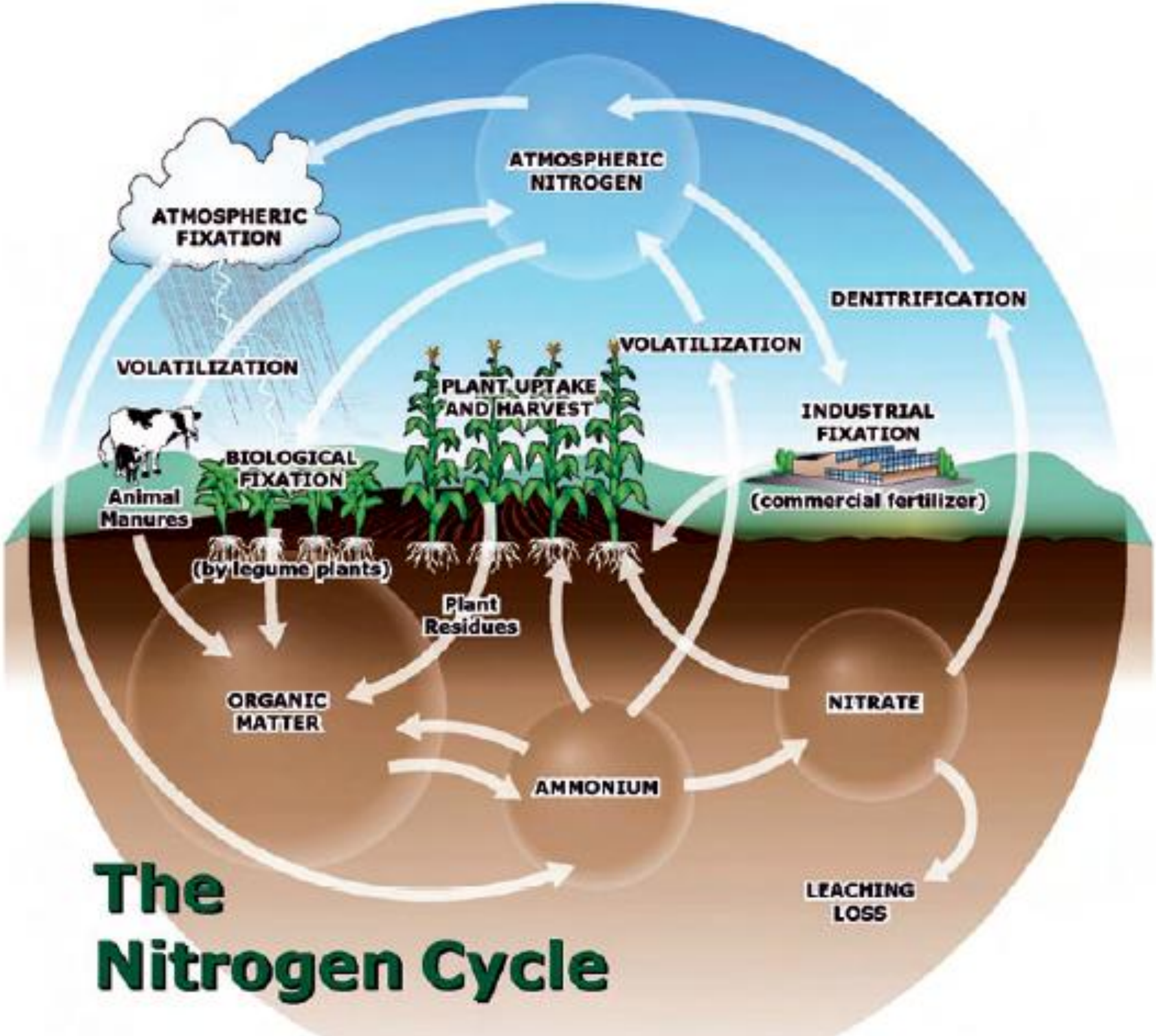
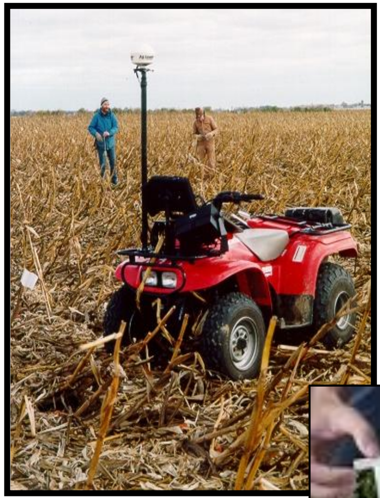


Fig. 1. Abbreviated general N cycle. Because the N cycle is more complex than other nutrients, timing discussions are most commonly centered on N fertilizer.

IPNI

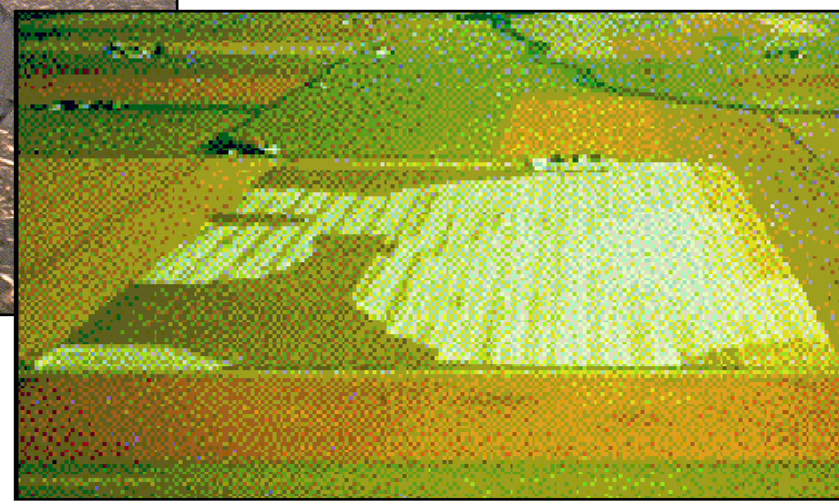
Right Rate

- **Assess soil nutrient supply and plant demand.**
- **Tools**
  - **Soil testing and plant analysis**
  - **Remote sensing**
  - **Yield monitor data**
  - **GIS mapping and analysis**
    - ***ArcGIS, FarmWorks, GeoAgro, etc.***
  - **Data integration and interpretation; modeling**
    - ***Hybrid-Maize; Maize-N***
  - **GIS analysis**
    - ***Grid or zone sampling***
    - ***Field level nutrient budget and GIS analysis***
  - **Variable-rate application**



IPNI

VRT - Variable Rate Technology



Field average is not good enough…”fine-tune” management for high yields.

Interactions for Right Rate

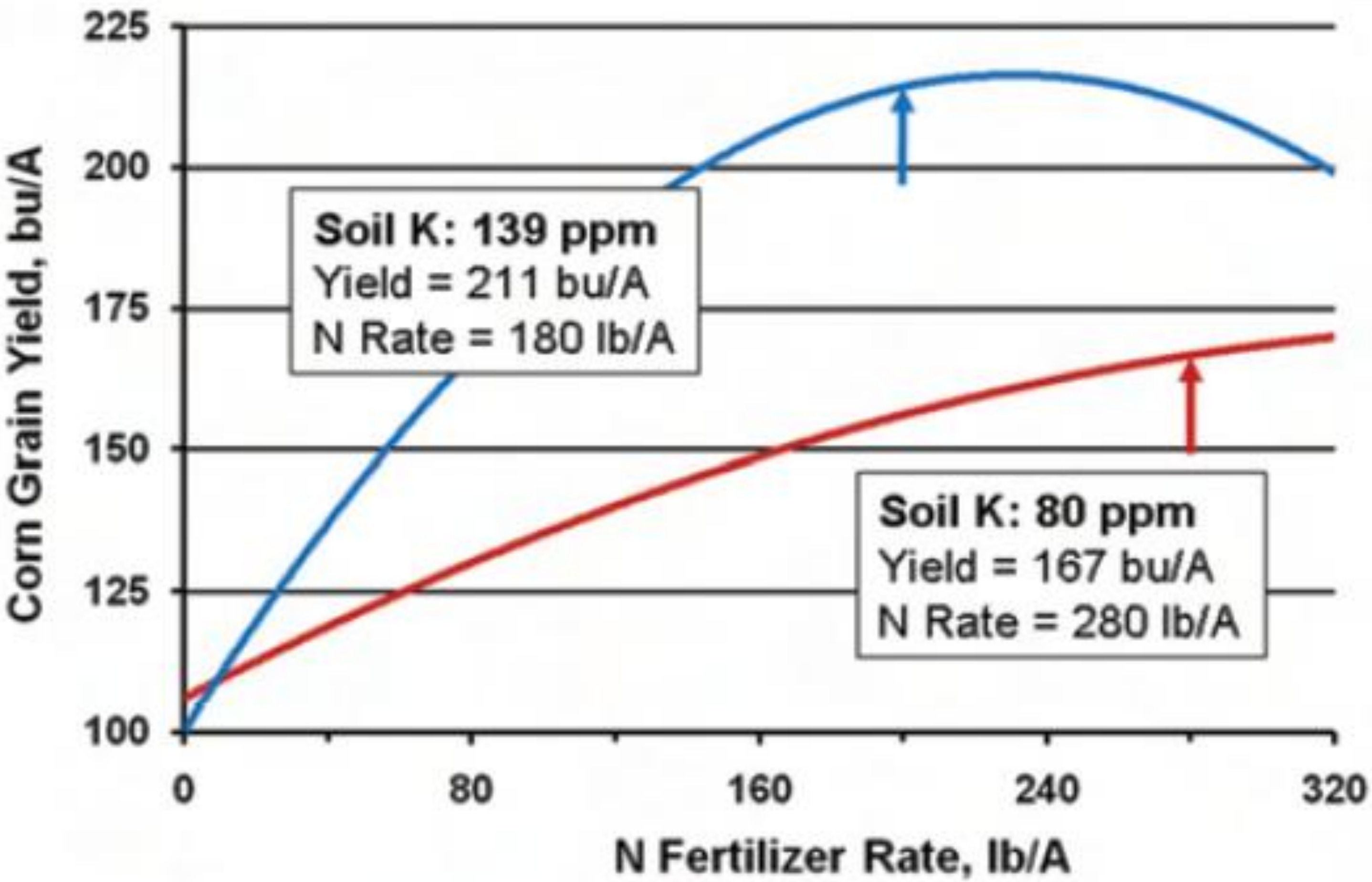
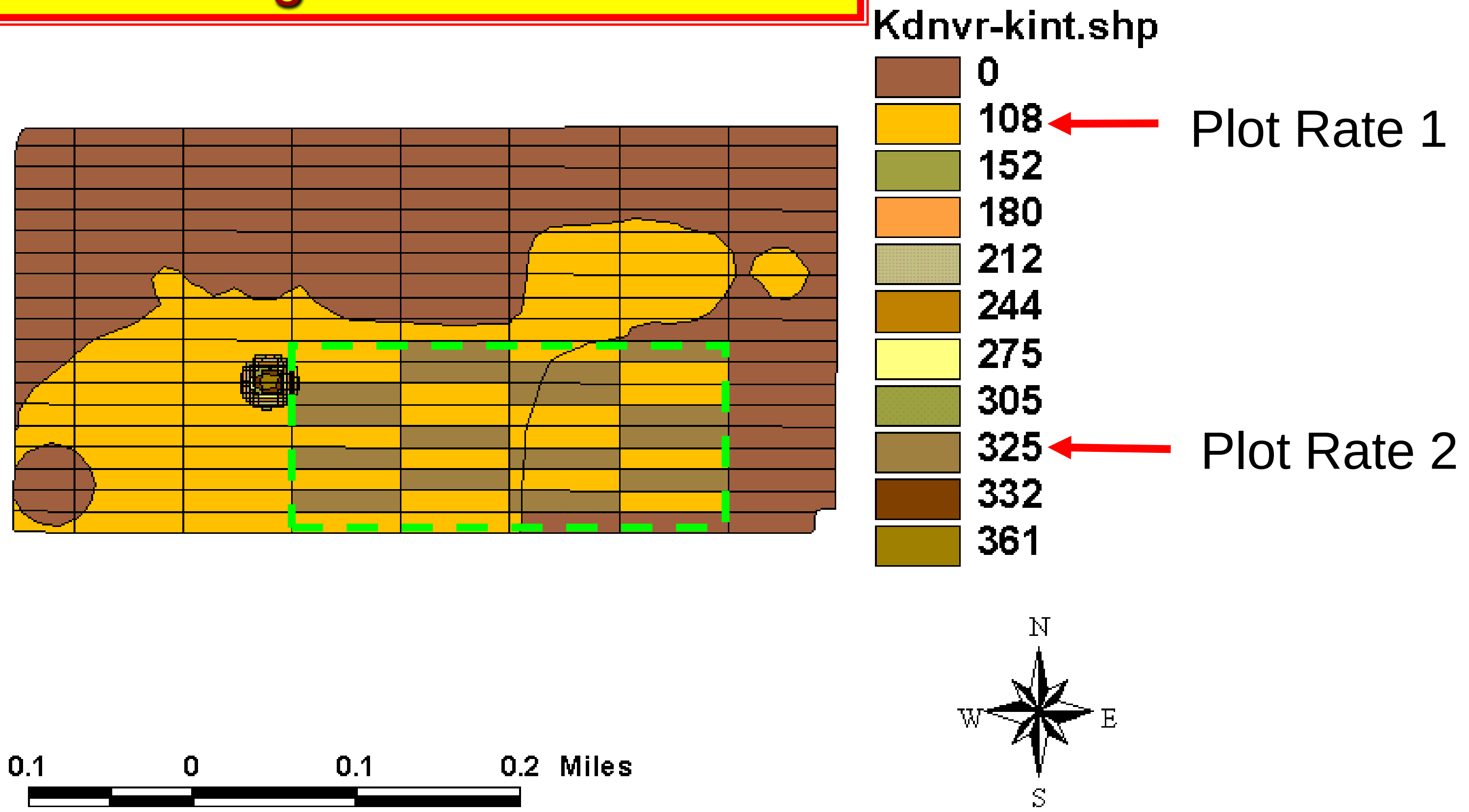


Fig. 1. High yields of corn are obtained with less N when other nutrients, such as K, are present in adequate concentrations (Ohio). Balanced nutrition is key to improving yields and minimizing N fertilizer loss. *Source: Murrell and Munson. 1999. Better Crops 83(3):28–31.*

On-Farm Research

-Building a local database

-Fine-tuning recommendations



Are Our Soil Test Goals Adequate for High Yield Systems?

Treatment	P_1 Soil Test (ppm)	K Soil Test (ppm)	Corn Yield (bu/A)	P_1 Soil Test (ppm)	K Soil Test (ppm)	Soybean Yield (bu/A)
Standard P and K Soil Tests	20	161	152	32	184	57
High P and K Soil Tests	32	237	190	41	222	57

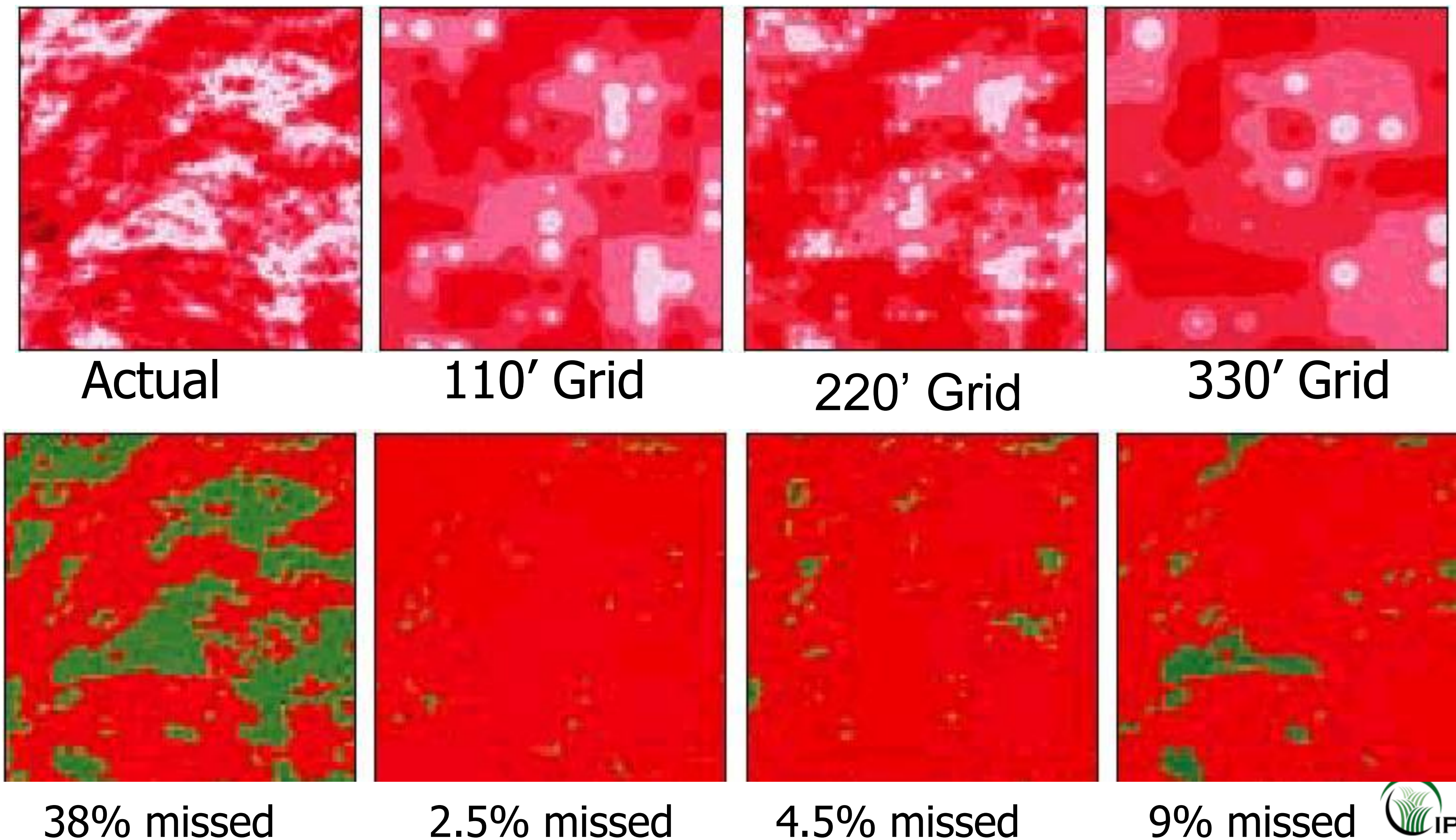
38 bu/A (2.3 T/ha) more corn!!

Grid Sampling vs. Field Average

640 acres --- Central Illinois

Based on over 1 million soil sample points

(Bullock, IL, _BETTER CROPS_)



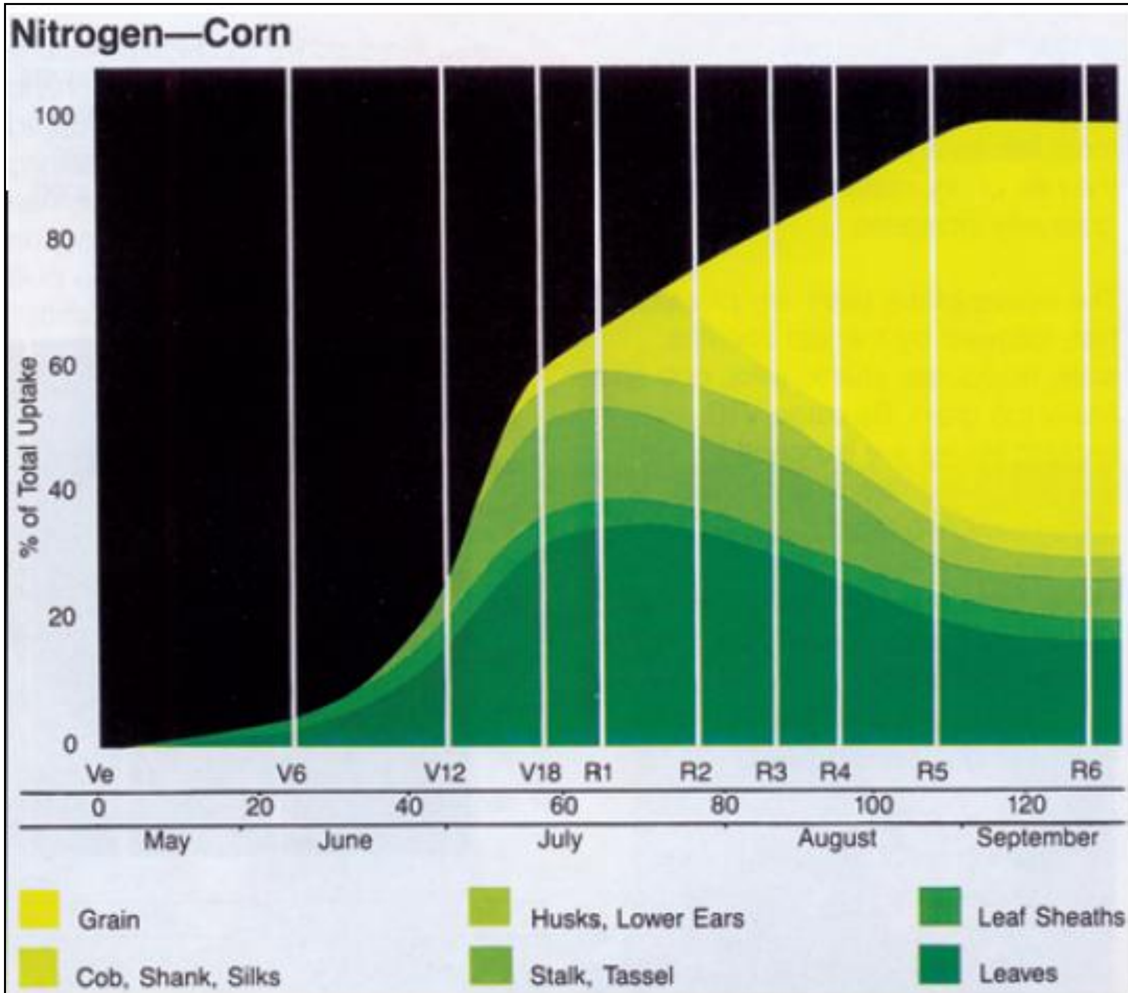
Right Time

- **Assess dynamics of crop uptake, soil supply, and logistics of field operations. Determine timing of nutrient loss risks.**
- **Tools**
  - **Plant and soil analysis**
    - ***With GPS, GIS, VRT application***
  - **Nutrient sensing**
    - ***Soil sensors --- pH, K, organic matter, etc.***
    - ***Greenseeker***
    - ***SPAD, Cardy meter, color charts***
  - **Weather monitoring**
    - ***Simulation models***
  - **Integrated remote sensing and GIS analysis**





Uptake Timing



Know the timing of nutrient uptake throughout the growing season

Fig 2. Corn N uptake throughout the growing season (SOURCE: Ritchie et al., 1993).

Right Place

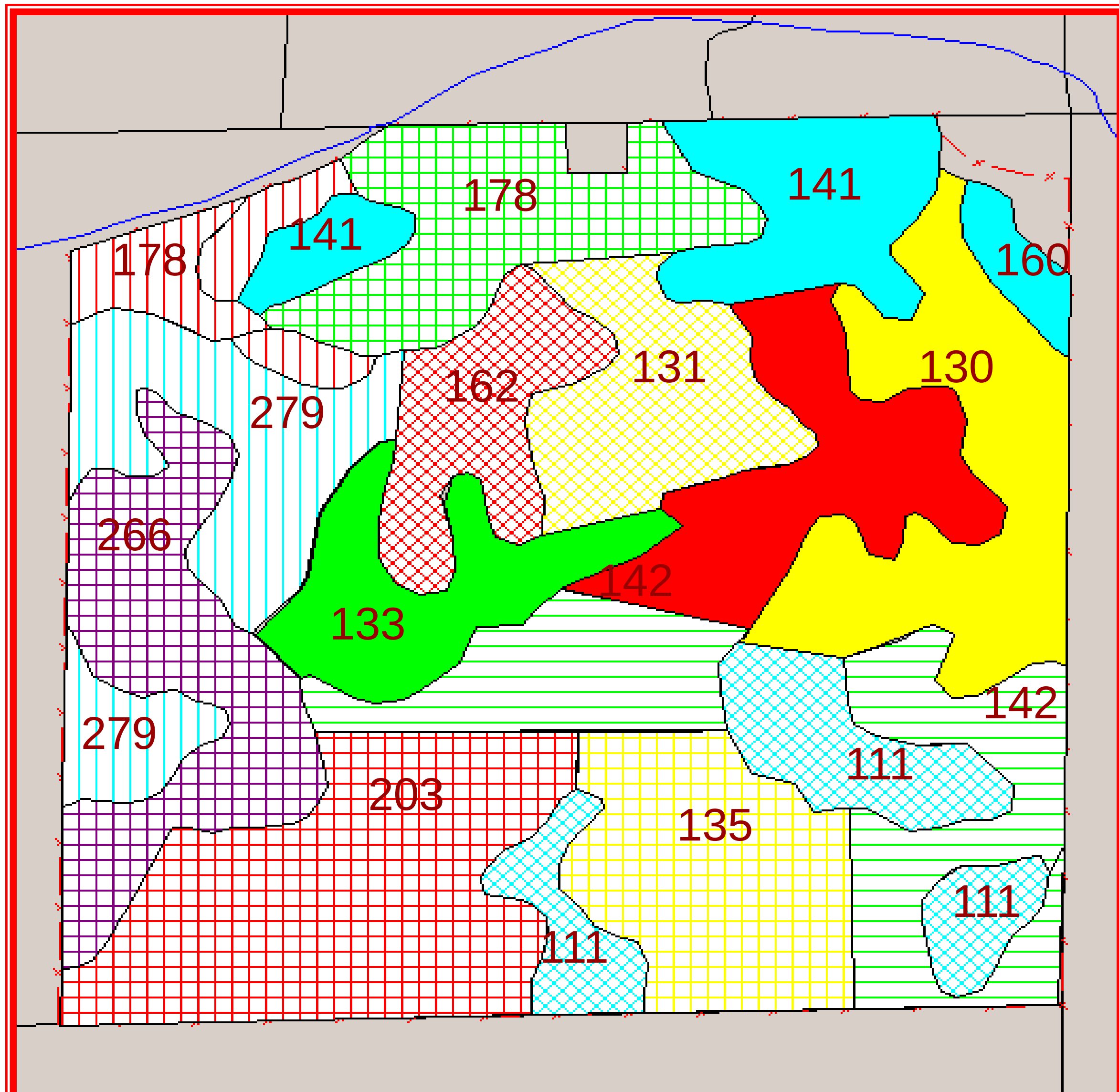
- Recognize root-soil dynamics. Manage spatial variability within the field to meet site-specific crop needs and to limit potential losses from the field.
- Tools
  - Models
  - GIS database and maps
  - Digital soil survey
  - RTK guidance and placement systems

Managing K Variability

- **Field Average**
  Soil test: 170 ppm
- Total Applied:
  None

- **Site-Specific**

  Soil Test Range:
  111 – 279 ppm
  Total K Applied:
  10032 lb K
  (4550 kg K)



35 bu/A more corn!

Plant Uptake Varies with Depth

Percentage of Phosphorus Uptake by Corn
from Different Depths in Selected Soils.

Soil Depth (in)	Miami Silt loam	Dodge Silt Loam	Parr Silt loam	Kewaunee Silty-clay loam
	----*% of total P Uptake*---			
0-6	36.4	43.1	27.0	19.4
6-12	45.9	33.3	23.7	41.8
12-18	6.0	11.7	12.1	21.8
18-24	5.1	8.4	6.5	17.0
24-30	6.6	3.5	30.8	---

Source: Murdock and Englebert (1958)

1. **Affected by tillage, moisture/drainage, fertilizer placement, etc.**
2. **Genetic modification of root system since this research was done.**

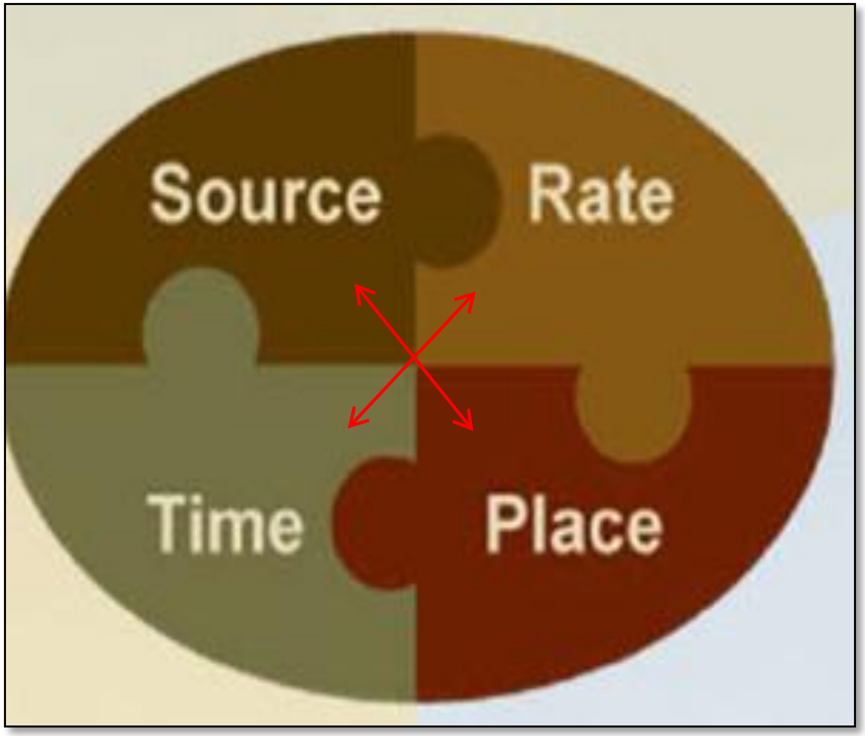
Has the pattern changed ?

IPNI

Interactions are Important

The right source, rate, time, and place are *interdependent* considerations in selecting the proper management for any individual site.

The 4Rs **work together** for best management.

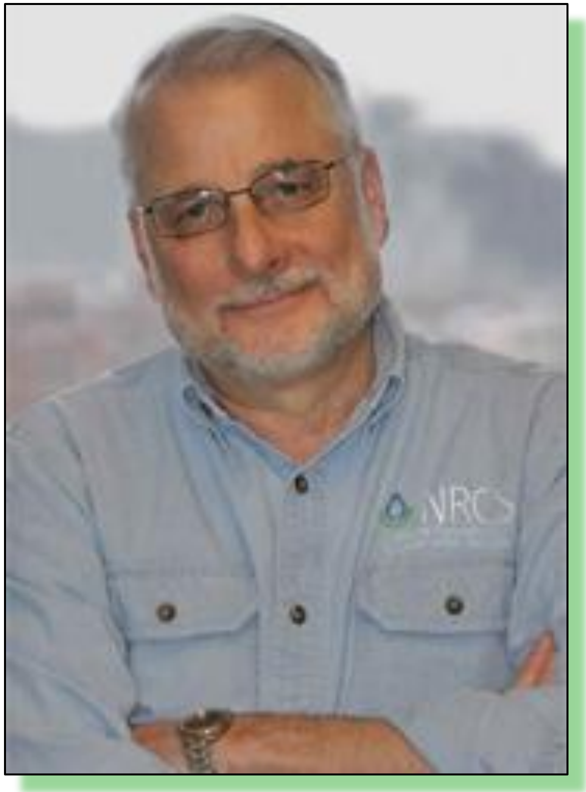


Think “Systems” Management

- **Right management**
  - Components interact for management decisions.
- “**System**” considers:
  - all component **practices**,
  - the **data** (information).
  - **Results** of the management decisions.
    - ***Agronomic*** *responses (yield) .*
    - ***Economic*** *evaluation.*
    - ***Environmenta****l consequences.*
- *Where do fluids fit?*
  - *Timing*
  - *Placement*
  - *Source*
  - *Rate control*

IPNI

Conservation Impact of High Yield Systems



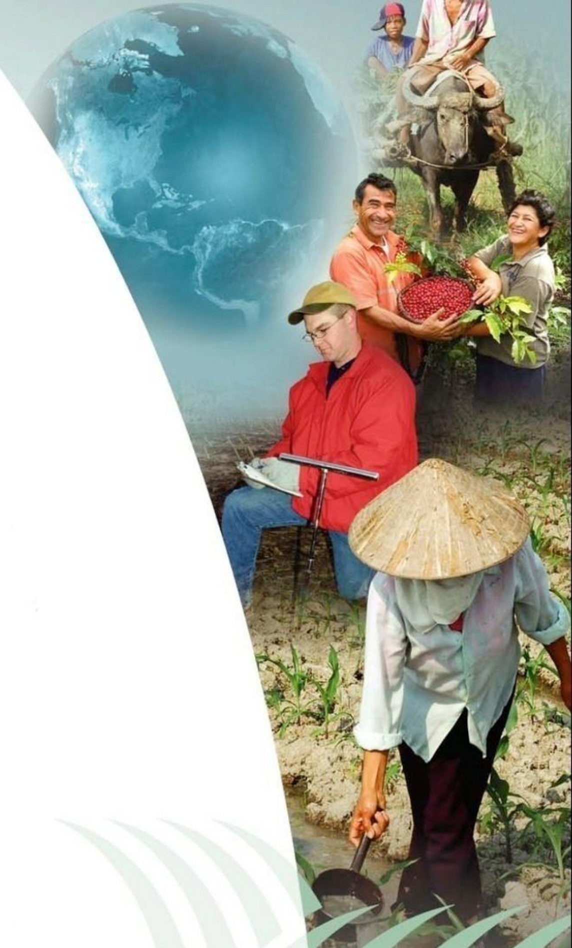
…build nutrient management plans around the concept of *right source, right rate, right place, right time*…

…manage for high yields on our more productive lands, so that we can reduce the need to put marginal land into production…

USDA-NRCS Chief, Dave White
National Association of Conservation Districts Annual Convention
Orlando, Florida, February, 2010

IPNI

IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE



***"…whoever makes two ears of corn,
or two blades of grass to grow
where only one grew before,
deserves better of mankind,
and does more essential service to his country than the
whole race of politicians put together."***

--- from Gulliver's Travels

Early passion for high yield corn

Illinois 4-H High Yield Contest---1965

Iroquois County Winner

146 bu/A

Maximum Yield Think Tank---Indiana mid-1970’s

"Fine tuning . . . removing the next limiting factor" **W. L. Nelson**

Purdue Extension




185 bu/A 1st year

Purdue 300/100 Project

After 3 years 235/85

300 bu/A Producers – 1970s & 1980s

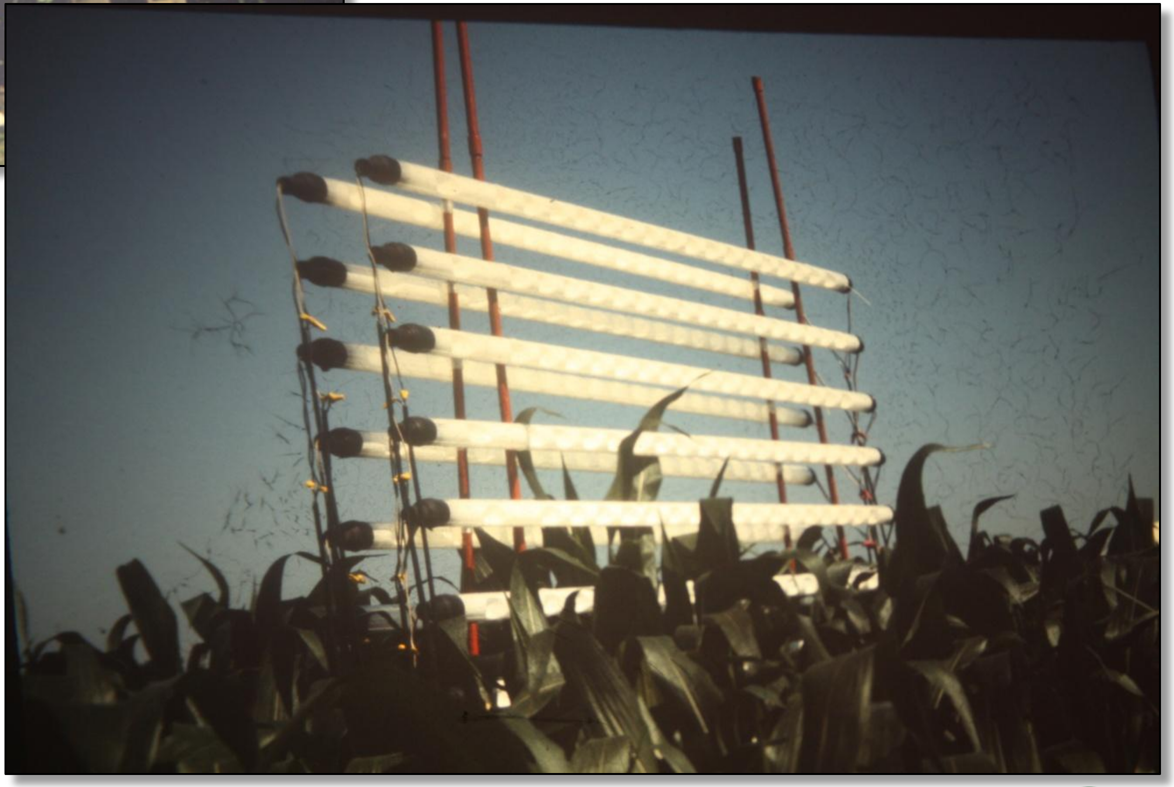
Researchers

- Roy Flannery – New Jersey (Rutgers)
- Sterling Olsen – Colorado State U.
- Fred Welch – U. of Illinois
- Bob Lambert – U. of Illinois

Farmers

- Herman Warsaw – Illinois - 370 bu/A
- Roy Lynn, Jr. – Michigan – 321 bu/A
- Schmidt Brothers – Nebraska – 306 bu/A
- Francis Childs – Iowa – 393 bu/A (?)

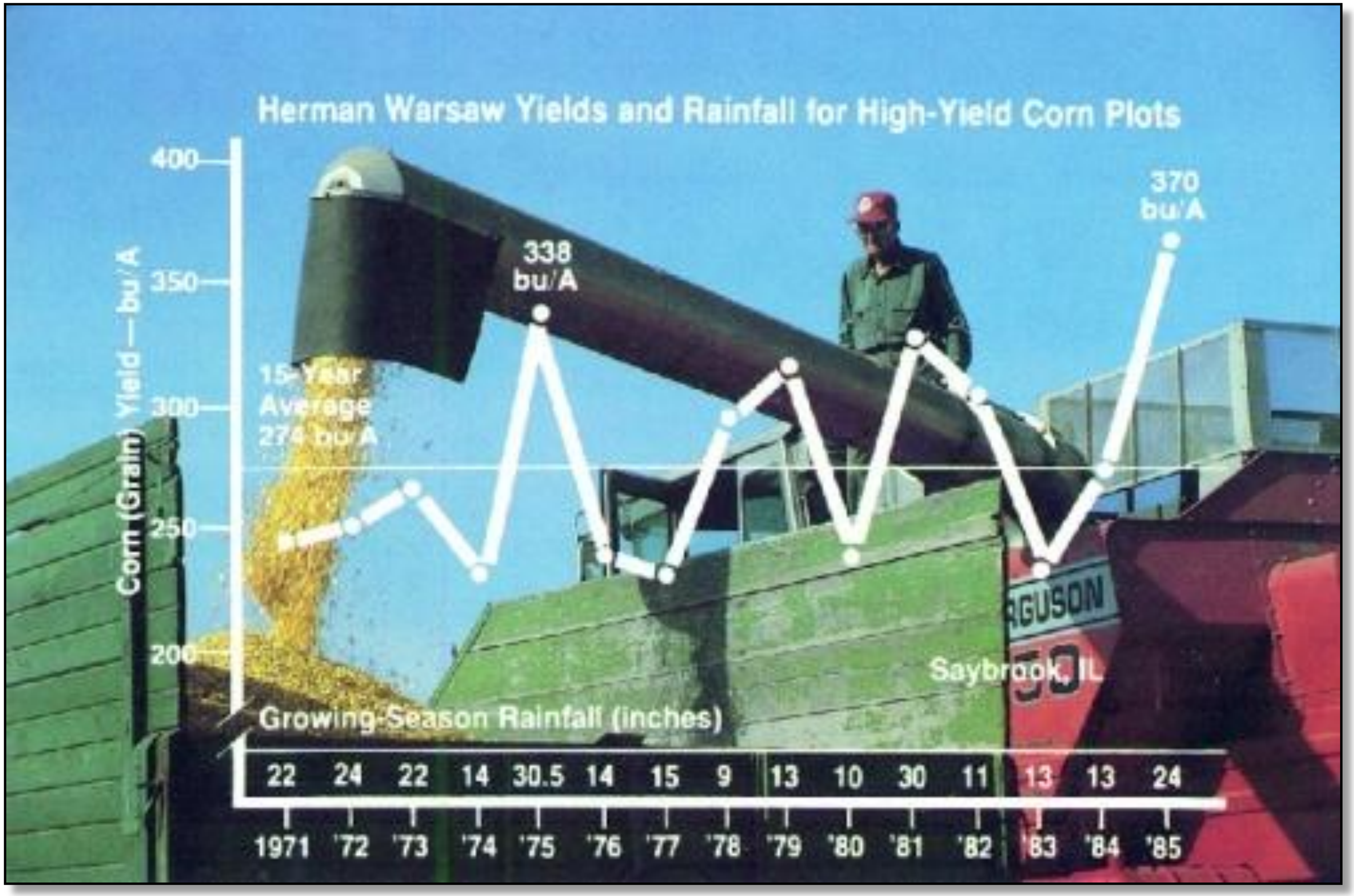
IPNI



Fred Welch
University of Illinois

307 bu/A

Herman Warsaw---
---World Record Corn Producer



370 bu/A = 23.2 metric tons/ha in 1985

Soil Tests on Herman Warsaw's 338 bu/A Field
1978

TABLE 1. Soil test results collected from Herman Warsaw's farm in March 1978.

		Sample depth, inches					
		0-3"	**3-6"**	**6-9"**	**9-12"**	**12-18"**	**18-24"**
P-1, lb/A	Normal production area	202	134	76	38	28	20
	High yield-lighter subsoil	234	192	58	20	12	8
	High yield-darker subsoil	252	204	108	42	44	36
	Fence row sample	44	26	8	6	6	4
K, lb/A	Normal production area	914	470	346	348	366	400
	High yield-lighter subsoil	740	404	270	232	300	382
	High yield-darker subsoil	1,400	556	412	332	328	320
	Fence row sample	652	452	320	338	284	262
O.M., %	Normal production area	6.6	5.4	5.5	5.4	4.1	3.6
	High yield-lighter subsoil	5.9	5.7	4.9	4.9	3.2	1.4
	High yield-darker subsoil	4.7	4.3	4.0	3.7	4.3	4.3
	Fence row sample	5.8	4.5	4.0	3.3	2.7	2.3
pH	Normal production area	5.5	5.7	5.7	5.6	5.8	5.9
	High yield-lighter subsoil	5.0	5.5	5.8	6.1	6.1	6.6
	High yield-darker subsoil	5.2	5.7	5.6	5.5	5.3	5.4
	Fence row sample	6.0	5.9	6.0	5.8	6.0	6.7

IPNI

Herman Warsaw's Soil Test Levels

TABLE 2. Soil test levels from a field that produced 370 bu/A corn in 1985.

Phosphorus P-1	161 lb/A
Potassium	800 lb/A
Magnesium	871 lb/A
Calcium	4,850 lb/A
Cation exchange capacity	23 meq/100g
Sulfate-S	35 ppm
pH	6.0
Organic matter	5.3%
Zinc (Zn)	Good
Iron (Fe)	Good
Boron (B)	Good
Copper (Cu)	Good

Table 2 shows the soil test results from samples collected in 1985, the year Warsaw produced the 370 bu/A yield. P and K tests are well-above University of Illinois recommendations. Nitrogen applied that year was approximately 485 lb/A, compared to the recommended level of 444 lb/A (based on 1.2 lb N per bushel of expected yield).

Was his 370 bu/A system profitable?

TABLE 3. Production costs, $/A, that produced 370 bu/A corn in 1985.

Input category	Cost per acre
Fertilizer	$201.05
Lime	$10.42
Herbicide/insecticide	$39.10
Seed	$26.72
Field operations, harvesting, and drying	$186.50
Total out-of-pocket costs	**$463.79**
Estimated land cost	$130.00
Total production costs	**$593.79**

Table 3 shows a partial budget for the production costs on the record-breaking field. The 370 bu/A yield would be $925 at $2.50/A; $1125 at $3.00/bu. In fact, breakeven price for out-of-pocket costs was $1.25/bu; $1.60/bu if land charge is included. Yes, it was a very profitable system.

Warsaw's Secret ….

- Farm plan designed for specific soil, climate, and management system
- Plan was site-specific…using the right management for the right reasons in the right place at the right time
- Concept fits anywhere in the world on any crop and soil management system
- "***There is no better fertilizer than a farmers footsteps***"

Francis Childs - Manchester, IA
National Corn Growers Assoc. Champion: 97 & 98

- 1997: 332 bu/A
- 1998: 338 bu/A
- 1999: (393 bu/A)

1/1000 Acre
44 ears

Moving Toward Higher Yields

154 bu/A (10.3 T/ha) Soybeans
---Kip Cullers, Missouri 2007

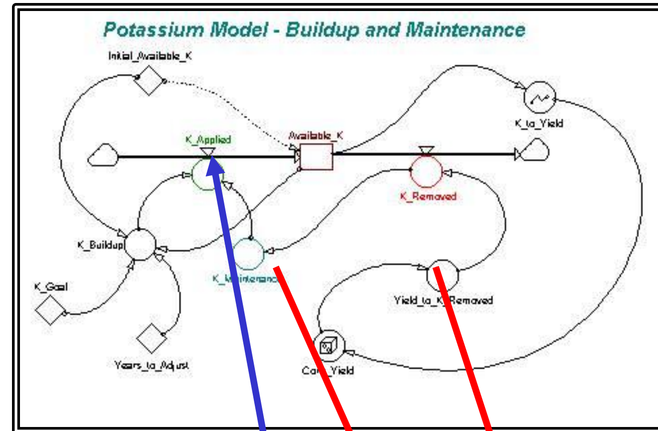
Also a champion corn grower

High yields require working with the details to fine-tune management practices.

Building a Local Management Database

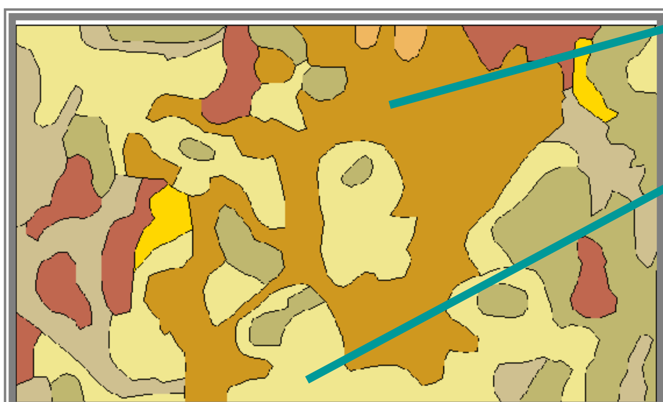
Integrating Data from Precision Ag

Precision Agriculture tools include more than equipment. The real power of precision ag is in **decision support** --- integrating data, models, GIS maps, etc., to support better-informed management decisions.



Potassium Model - Buildup and Maintenance

year	Available_K	K_Applied	K_Removed	Corn_Yield	K_Buildup	K_Maintenance
1	120.00	80.28	35.28	126.00	45.00	35.28
2	165.00	83.12	38.12	136.13	45.00	38.12
3	210.00	84.90	39.90	142.50	45.00	39.90
4	255.00	86.06	41.06	146.63	45.00	41.06
5	300.00	41.50	41.50	148.20	0.00	41.50
6	300.00	41.50	41.50	148.20	0.00	41.50
7	300.00	41.50	41.50	148.20	0.00	41.50
8	300.00	41.50	41.50	148.20	0.00	41.50
9	300.00	41.50	41.50	148.20	0.00	41.50
10	300.00	41.50	41.50	148.20	0.00	41.50

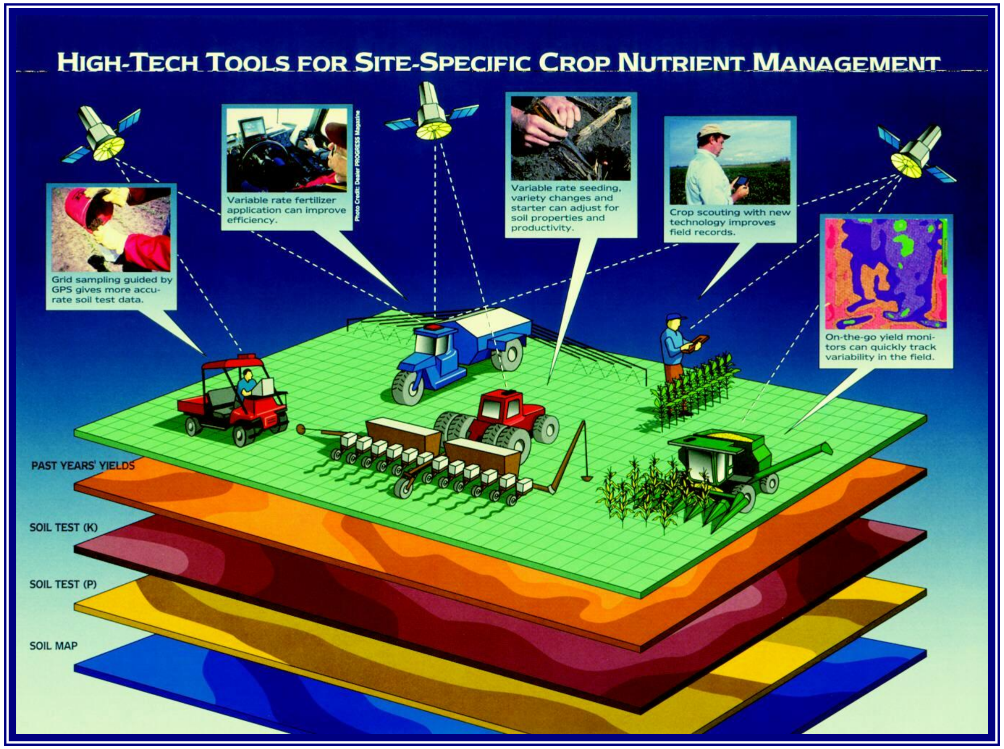


Consider the Whole System

Precision farming technology helps to <u>systematically</u> include all components to define the best fertilizer management system.

The real power of precision technology is in using ***GIS analysis*** to determine the ***interactions*** among data layers**.**

- use with research results
- make ***better-informed, site-specific*** decisions.



Field-Average Management Is Not Good Enough

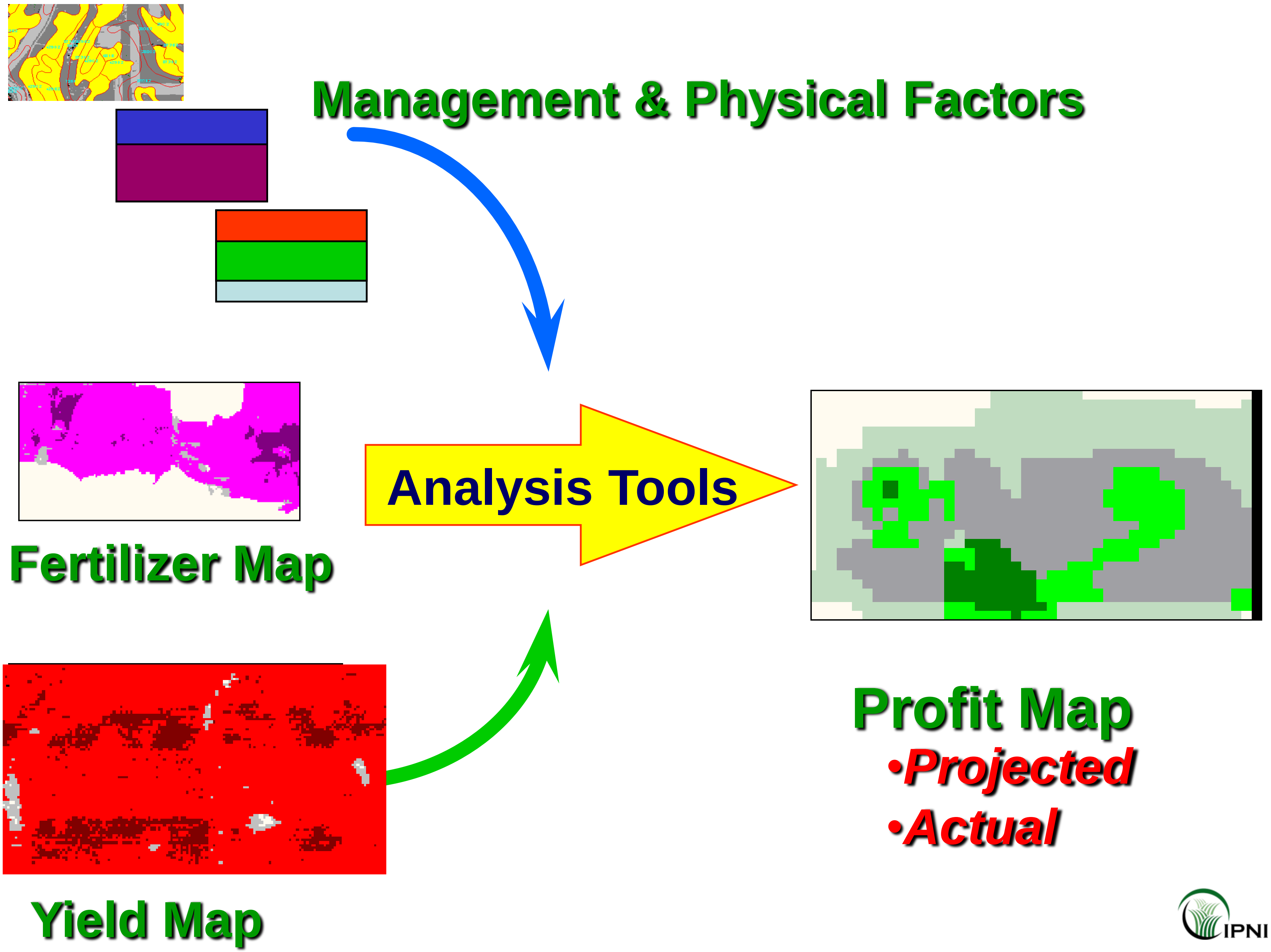
- Over-fertilize low yielding areas
- Under-fertilize high yielding areas
- Each year of field average management increases variability and potentially decreases productivity

Reviving High Yield Management

- Increased world demand
- Increased farmer awareness
- Untapped research information
- Better awareness of opportunity through site-specific management
- Better-trained dealers and farmers
- On-farm research
- More efficient use of resources and inputs

Management "Team"

- Farmer
- Resource providers
  - Landowners, farm managers
  - Investors
- Input suppliers
  - Seed, fertilizer, chemicals, machinery
- Information suppliers
  - NRCS, Extension, industry
  - Publications, meetings, field days, <u>internet</u>
- Markets
  - Grain companies, other farmers, <u>consumers</u>


Management & Physical Factors
Analysis Tools
Fertilizer Map
Yield Map
Profit Map
•Projected
•Actual
IPNI

Major Hurdles Ahead

- Lack of research on interactions
  - *Correlation among layers of GIS*
- Shortage of trained agronomists
  - *Education*
  - *Continuing education*
    - “Hands-on” field training
    - “Hands-on” computer training
    - Multi-tiered approach needed
  - *CCA program is helping*

- Need to revive **MYR** to set the bar for new genetics
- Need to revive **MEY** to study economic of new high yield systems management

Dare to Dream

Don’t hesitate to dream….be creative!

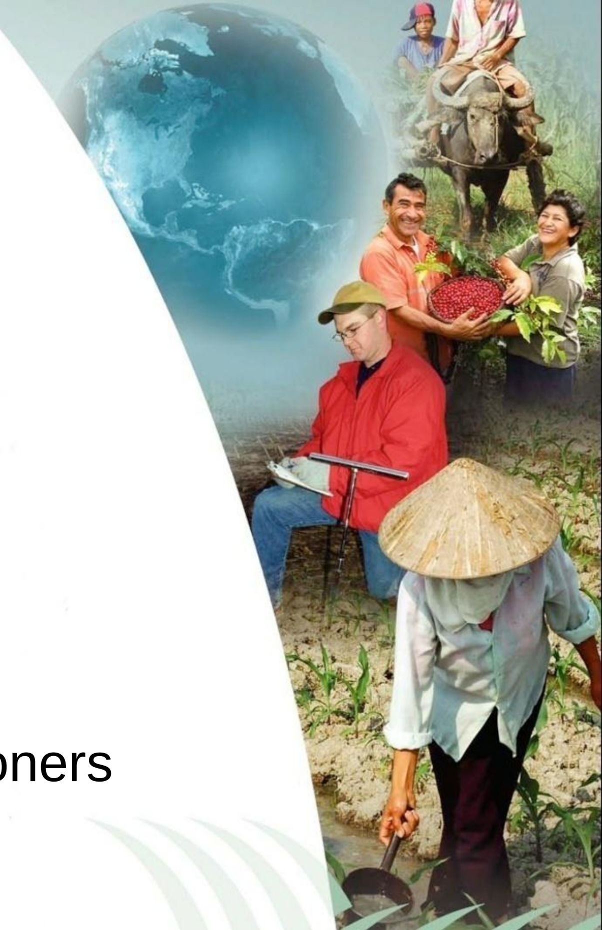
Danger in being too much in the reactive mode.

Bridge the gap between researchers and practitioners

Carry the science to the field.

Follow the dream….be proactive.

Be the facilitator of change---lead, *from in front or from behind*---but <u>be a leader !</u>



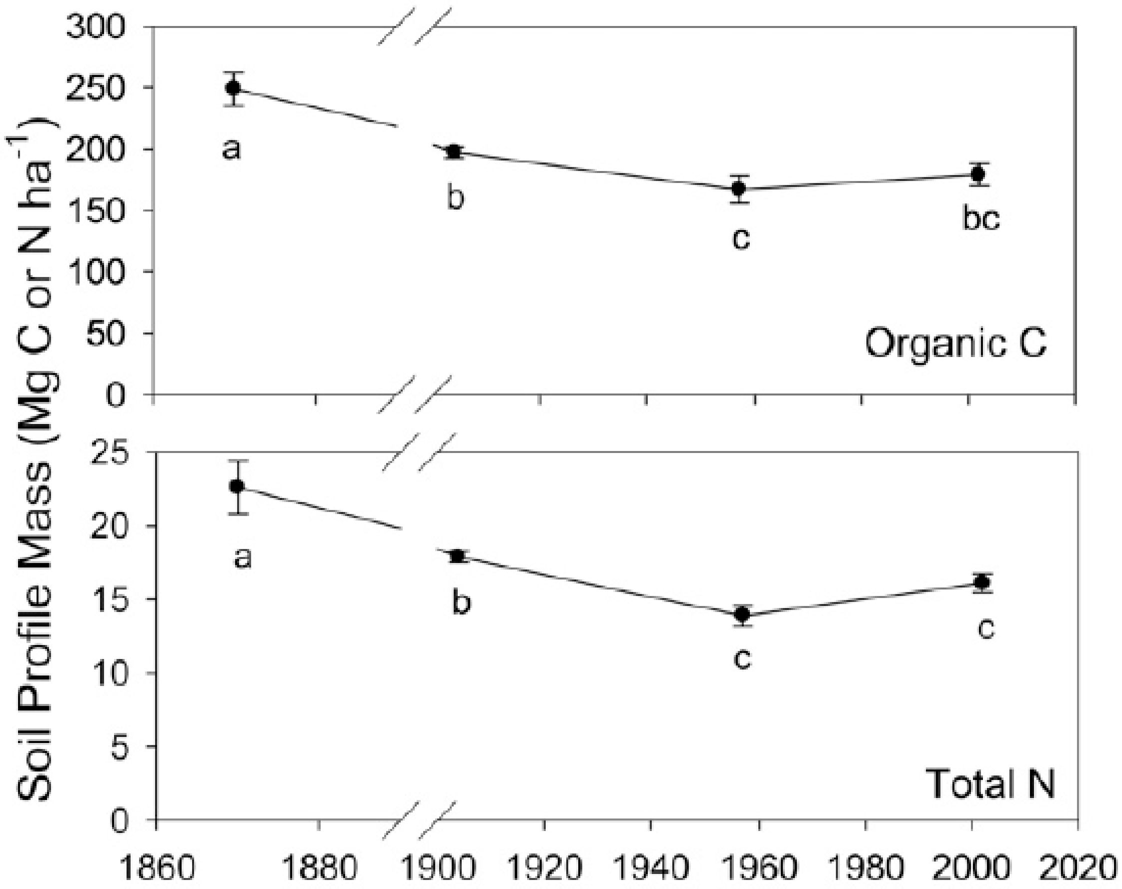
Illinois Council on Food and Agricultural Research

Soil Nutrient Resources

Are We Maintaining Our Base for the Future?

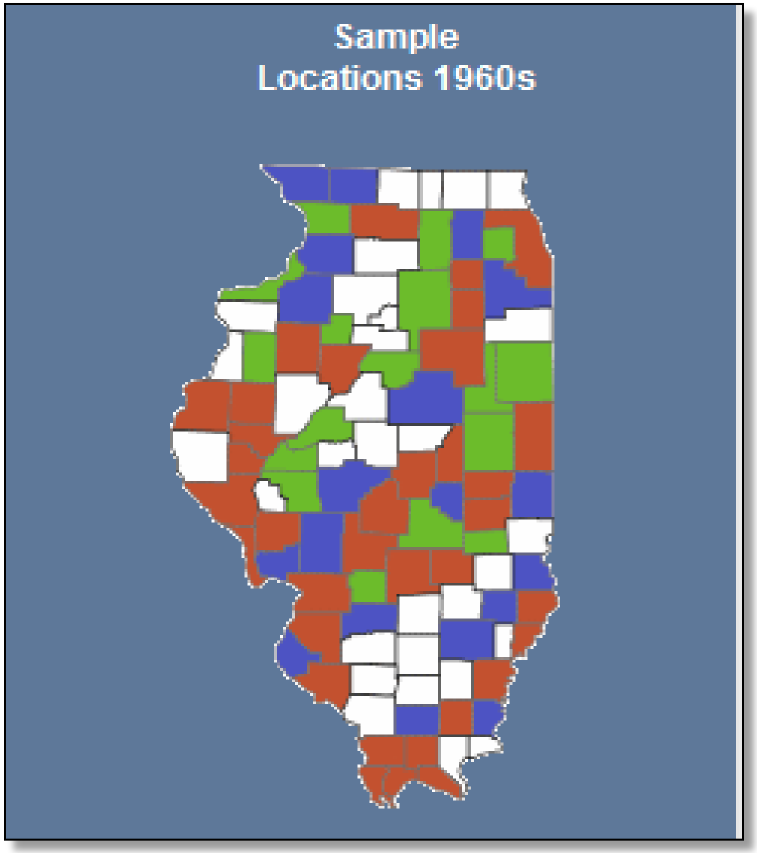
Long-Term Changes in Mollisol Organic Carbon and Nitrogen

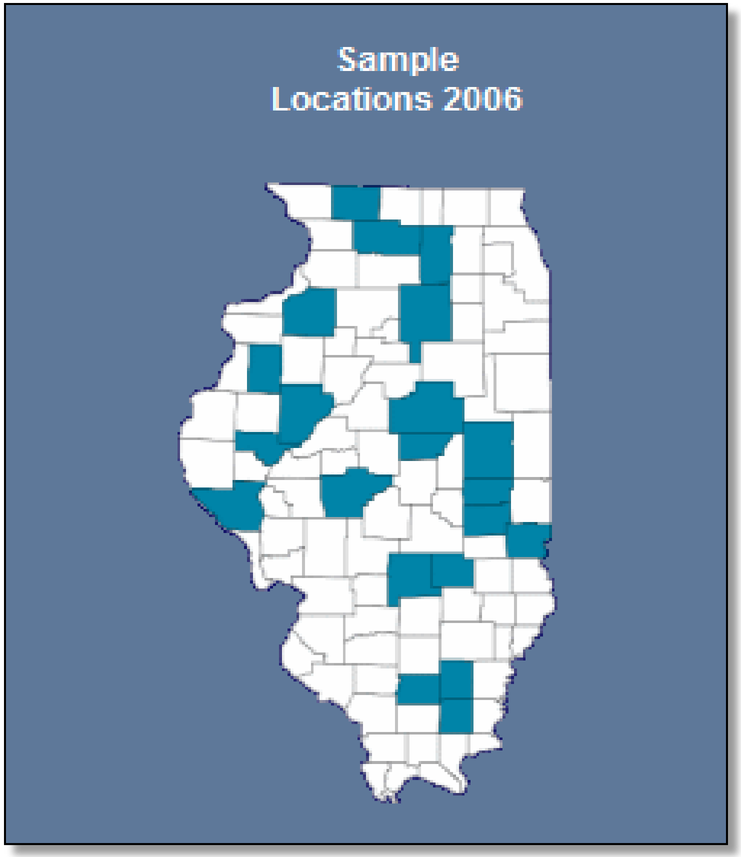
Mark B. David,* Gregory F. McIsaac, Robert G. Darmody, and Rex A. Omonode. 2009
J Environ Qual. 38 (1): 200.

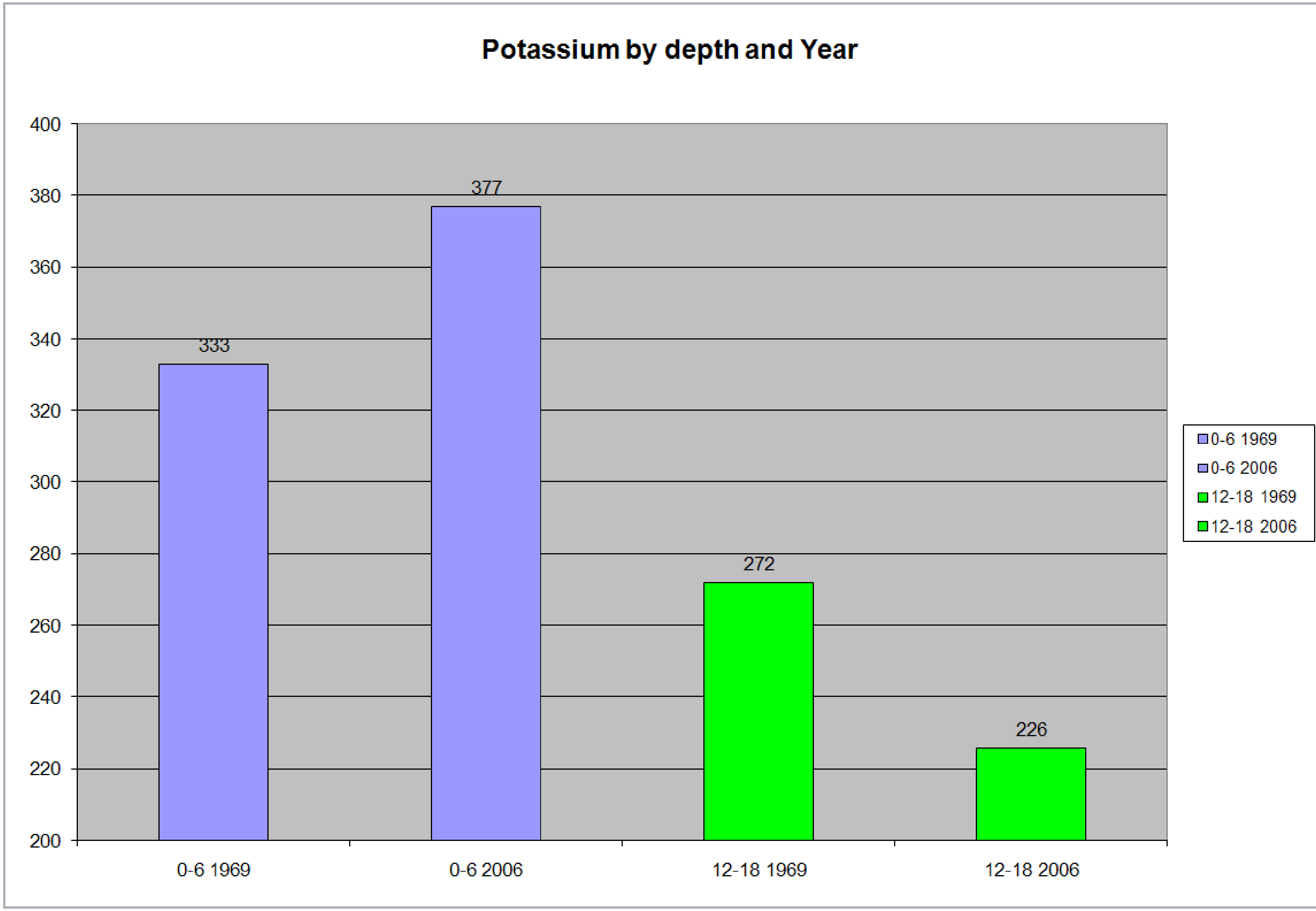


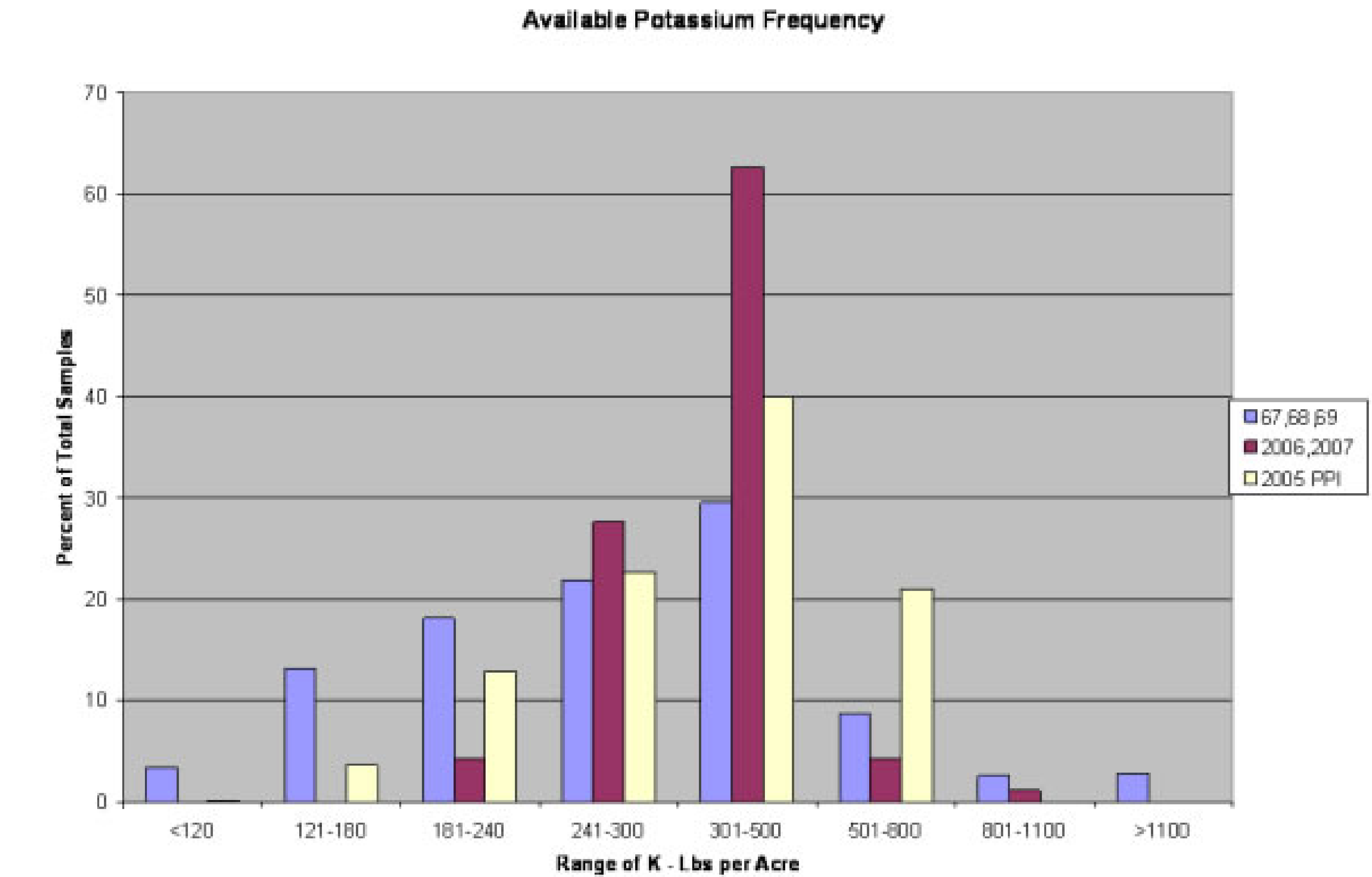
Mean organic C and total N profile mass by time period

IPNI/FAR Soil Test Change Project






Potassium by depth and Year
400
380
360
340
320
300
280
260
240
220
200
333
377
272
226
0-6 1969
0-6 2006
12-18 1969
12-18 2006
0-6 1969
0-6 2006
12-18 1969
12-18 2006



Available Potassium Frequency
Percent of Total Samples
70
60
50
40
30
20
10
0
<120
121-180
181-240
241-300
301-500
501-800
801-1100
>1100
Range of K - Lbs per Acre
67,68,69
2006,2007
2005 PPI

C-FAR
Illinois Council on Food and Agricultural Research

Sites for Subsoil Sampling from Archived and Map Validated Sites.

Dixon 1927 - Sampled by horizon

Ewing 1918 – Sampled by depth

LaMollie 1925 - Sampled by horizon

Lebanon 1927 - Sampled by horizon

Newton 1937 - Sampled by depth

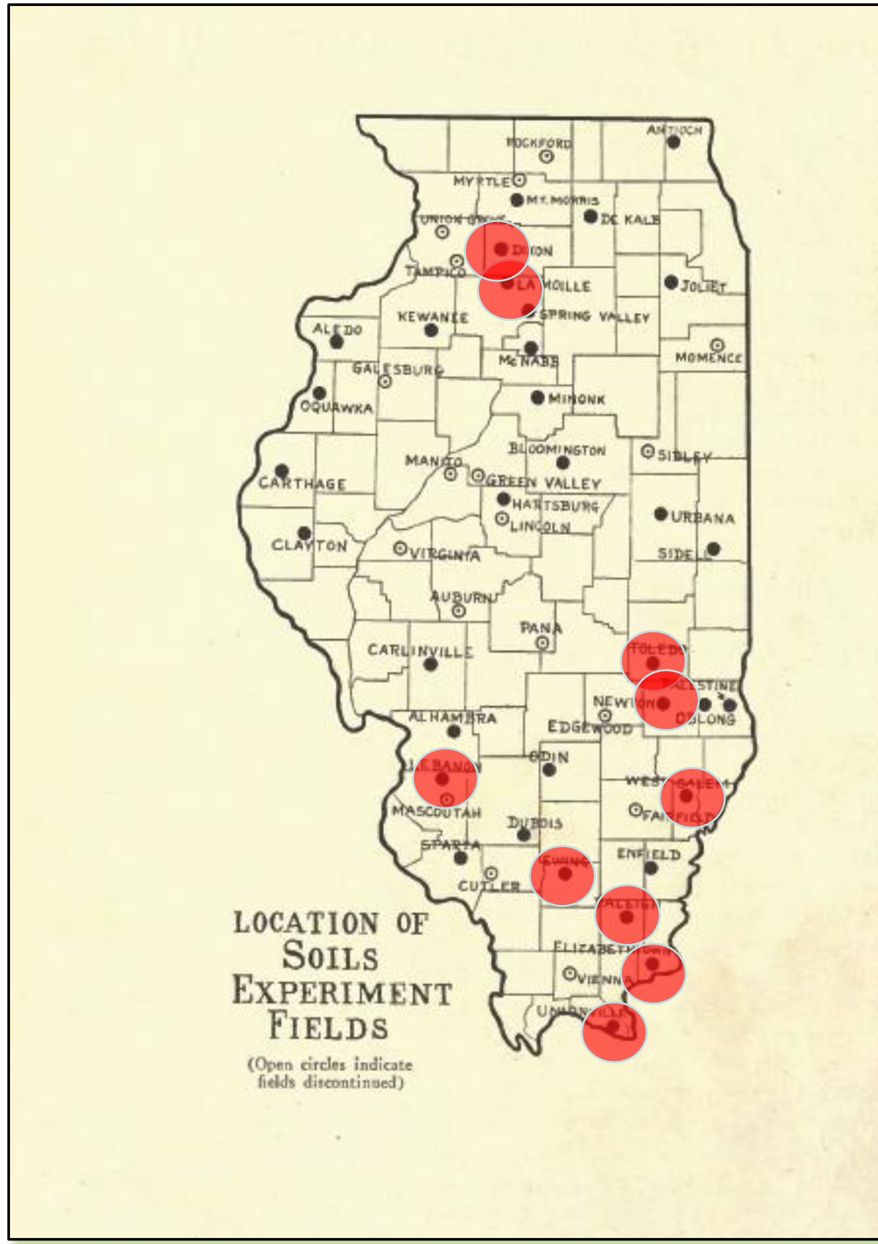
Raleigh 1918 - Sampled by depth

Toledo 1927 - Sampled by hoizon

Unionville 1927 - Sampled by horizon

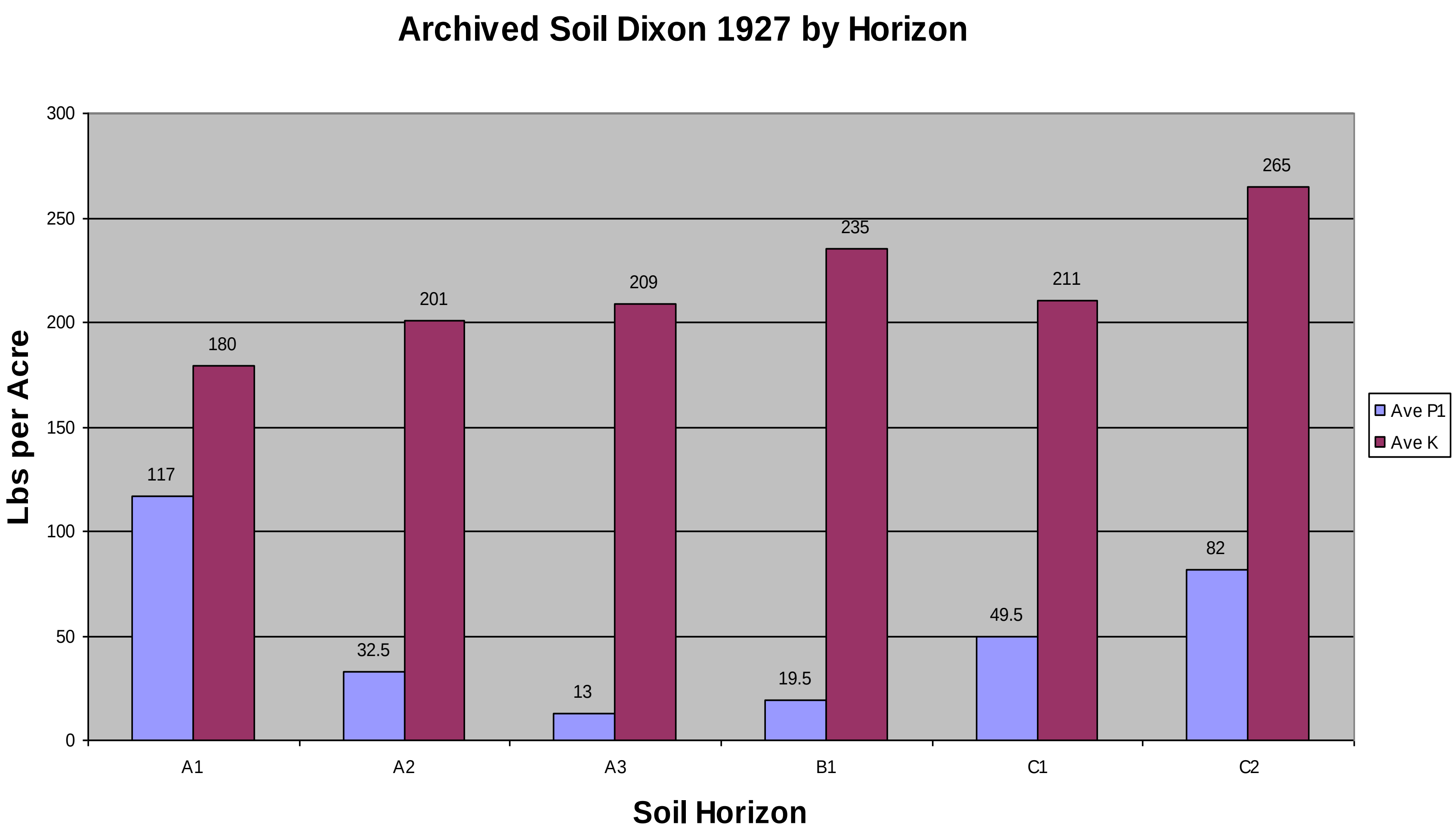
West Salem 1927 - Sampled by horizon

Antioch 1927 - Sampled by horizon



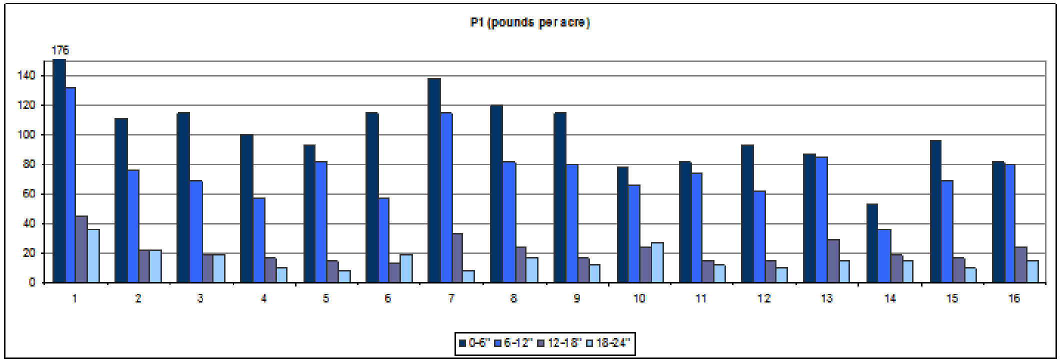
IPNI

Phosphate and Potassium Levels

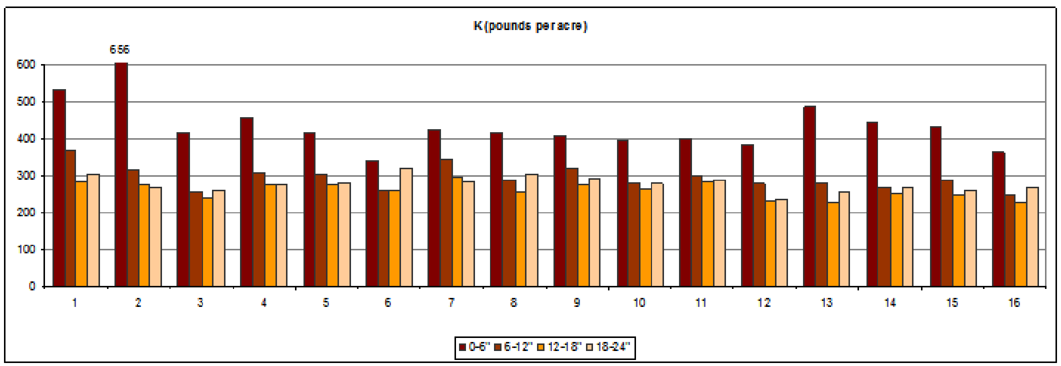


Dekalb County

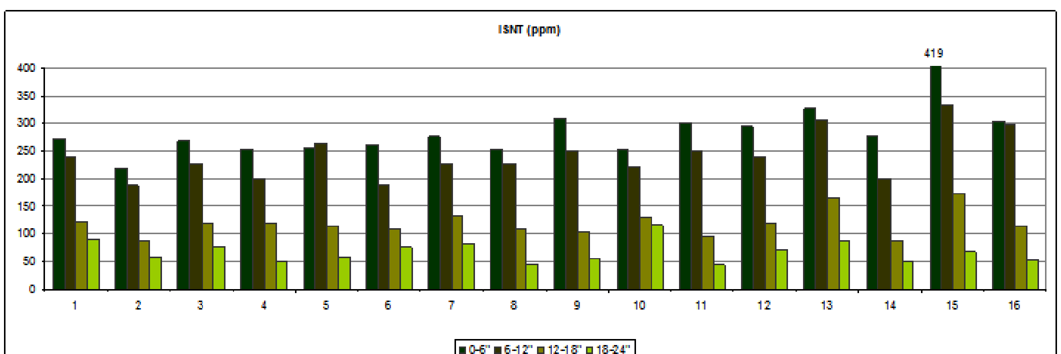
P1 Chart



K Chart

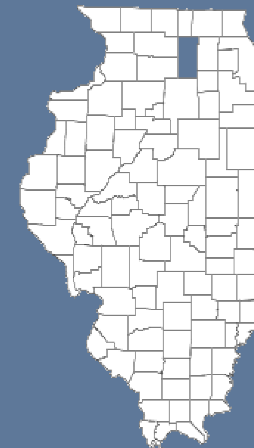


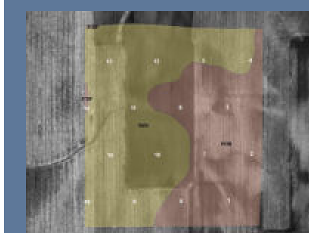
ISNT Chart



Paul Taylor

Rochelle, IL





state map

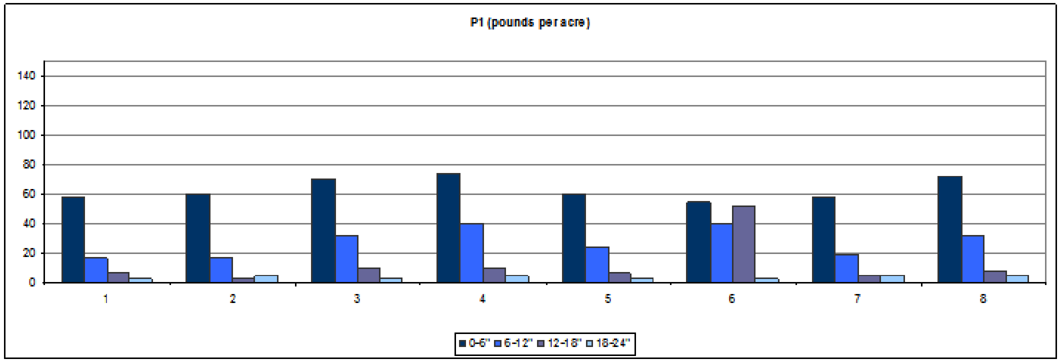
field map

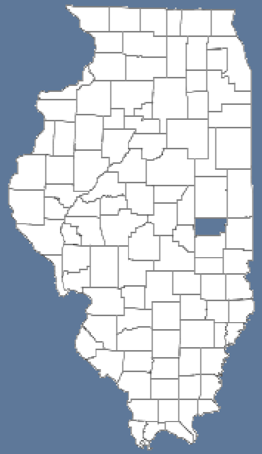
Douglas County

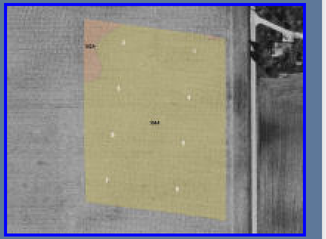
Eric Rund

Pesotum, IL

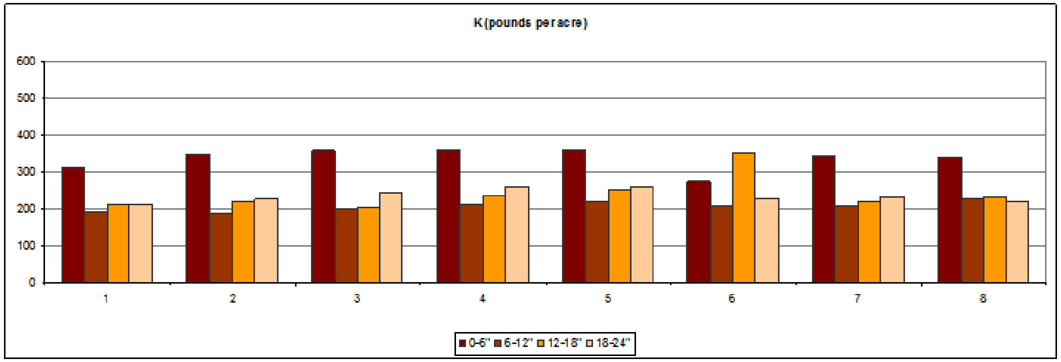
P1 Chart



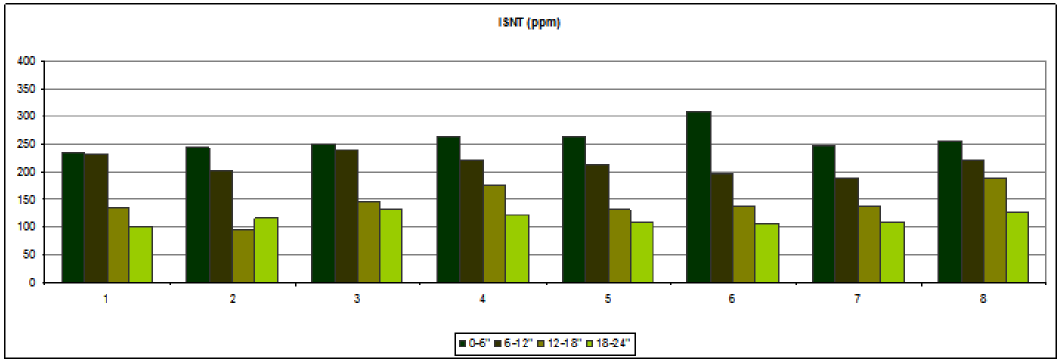




K Chart



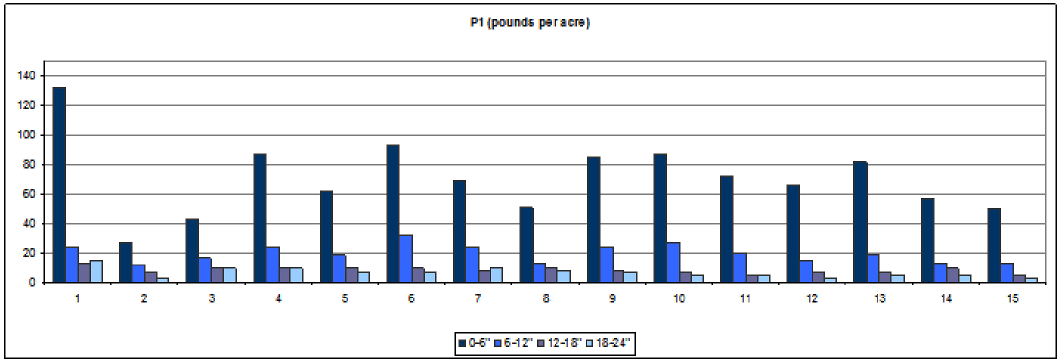
ISNT Chart



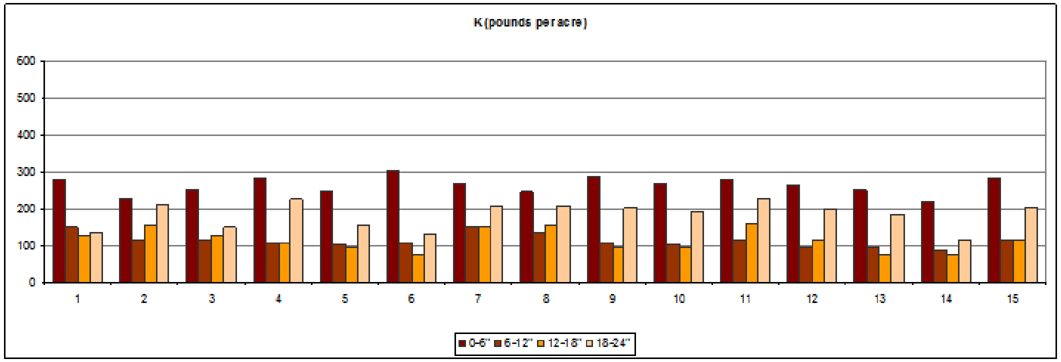
IPNI

Franklin County

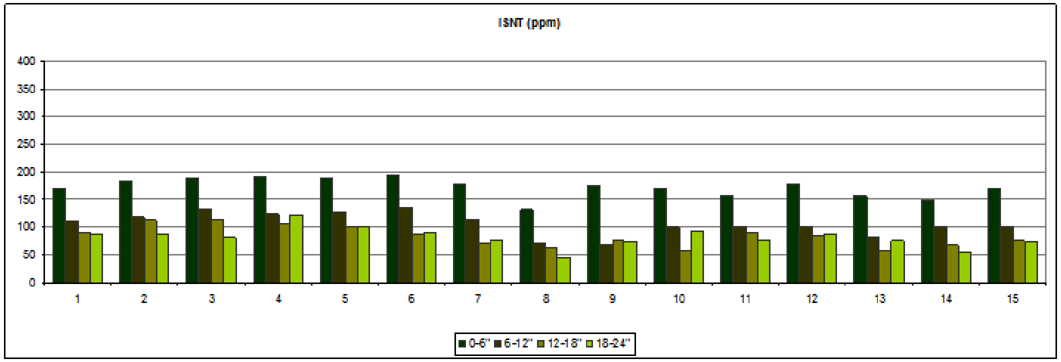
P1 Chart



K Chart

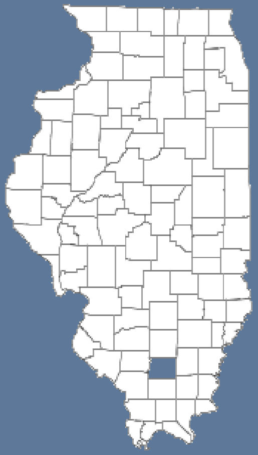


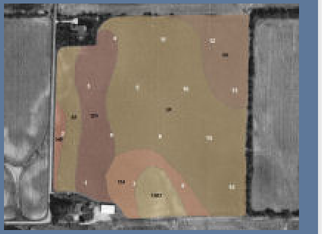
ISNT Chart



Kelly Robertson

Benton, IL





state map

field map

C-FAR
Illinois Council on Food and Agricultural Research

Sites for Subsoil Sampling from Archived and Map Validated Sites.

Dixon 1927 - Sampled by horizon

Ewing 1918 – Sampled by depth

LaMollie 1925 - Sampled by horizon

Lebanon 1927 - Sampled by horizon

Newton 1937 - Sampled by depth

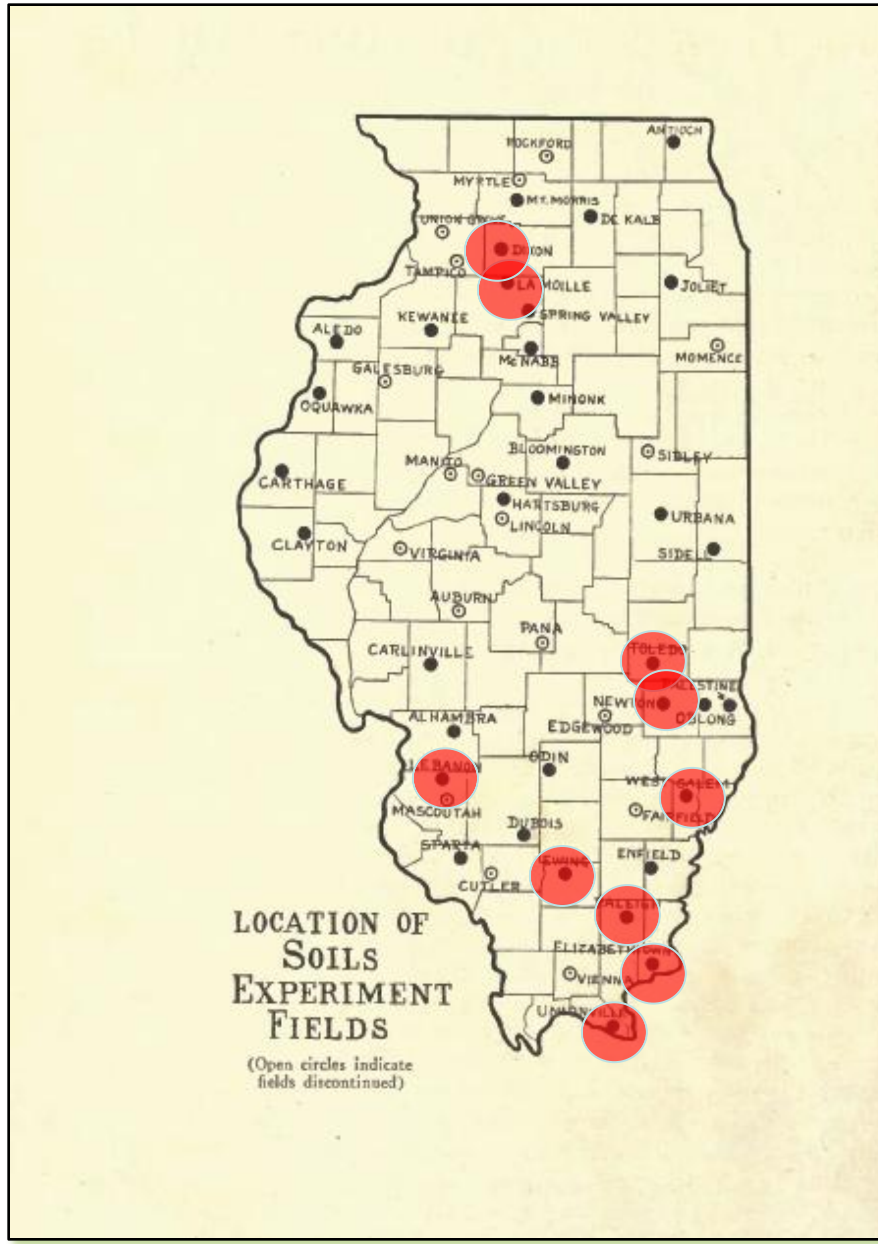
Raleigh 1918 - Sampled by depth

Toledo 1927 - Sampled by hoizon

Unionville 1927 - Sampled by horizon

West Salem 1927 - Sampled by horizon

Antioch 1927 - Sampled by horizon



IPNI

Better Technology – Better Data

- Developments in technology combining GIS, sensors, record-keeping, and monitoring of various parameters.
- Better data means ***better-informed decisions***

Information Management

- Assemble a database for each field
    - Soil survey---digitized if possible
    - Yield history---data and GIS maps
    - Weather data
    - Soil test and plant analysis
    - Fertilizer application---data and GIS maps
    - Production practice records
    - Scouting reports
    - Harvest data
        - *Yield, moisture, test weight, quality*
    - Data storage, backups, analysis
- Record of history
- “Roadmap” for the future

IPNI

Think "Systems" Management

- **Right management** requires thinking about how all of the **components**, and the **decisions** to be made about managing the crop, **interact** to produce the final product.
- A **"System"** considers all component **practices**, the **data** (information), and the **results**---**agronomic** responses (such as yield), **economic** evaluation, and **environmenta**l consequences of the management decisions.

You Can't Afford to Wait

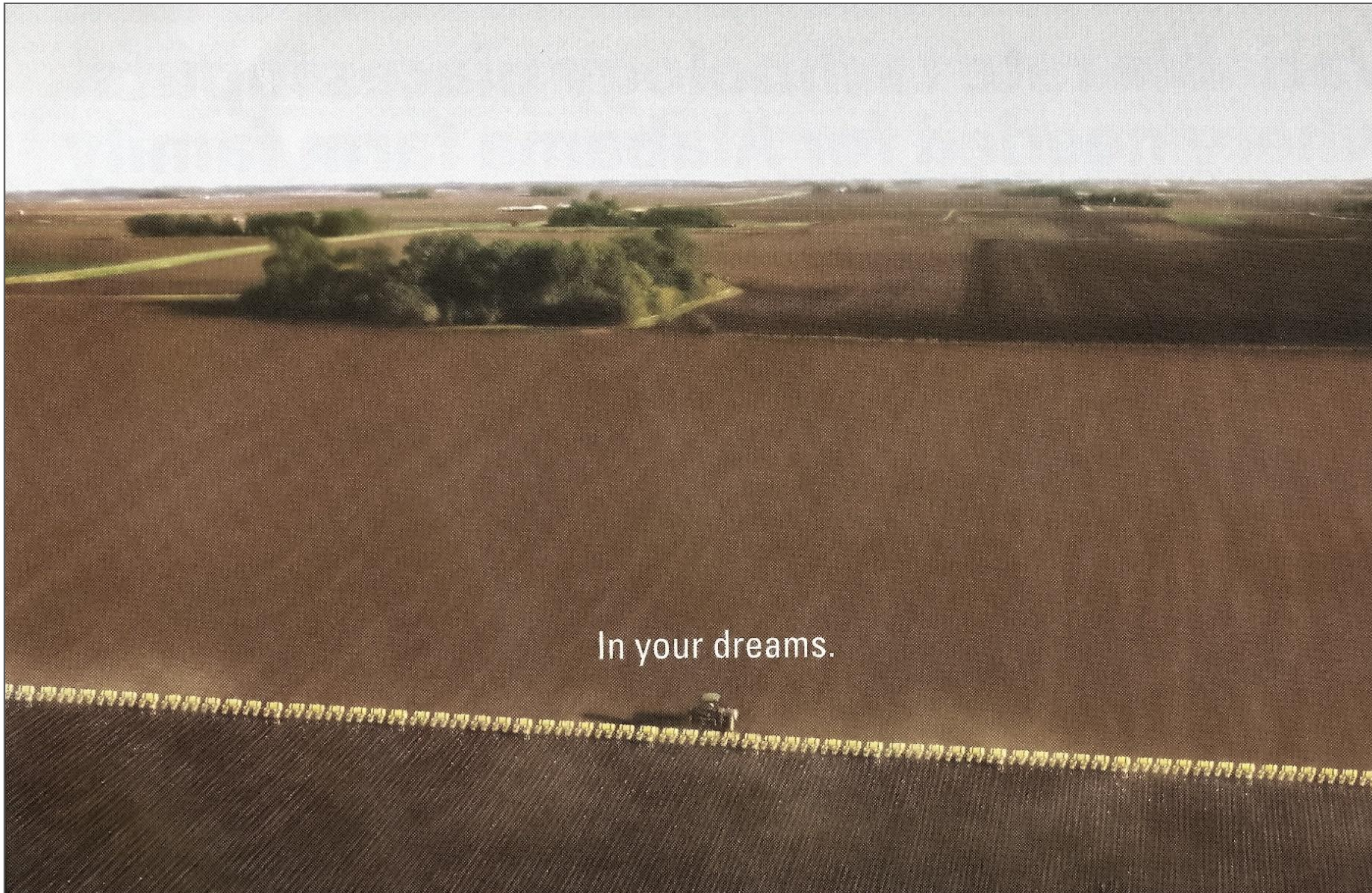
- Build high-yield management systems NOW!
- Putting a high-yield system in place prepares for the good years…so you can participate!
- New genetics and new technology are raising the bar.
- The average farmer is heading out-of-business in many areas.
- We work with 3 kinds of farmers:
  - *Some **make** things happen*
  - *Some **watch** things happen*
  - *Some **wonder** what happened!*

Focus on cutting costs per unit of production by managing fertilizer and other inputs to grow higher yields.

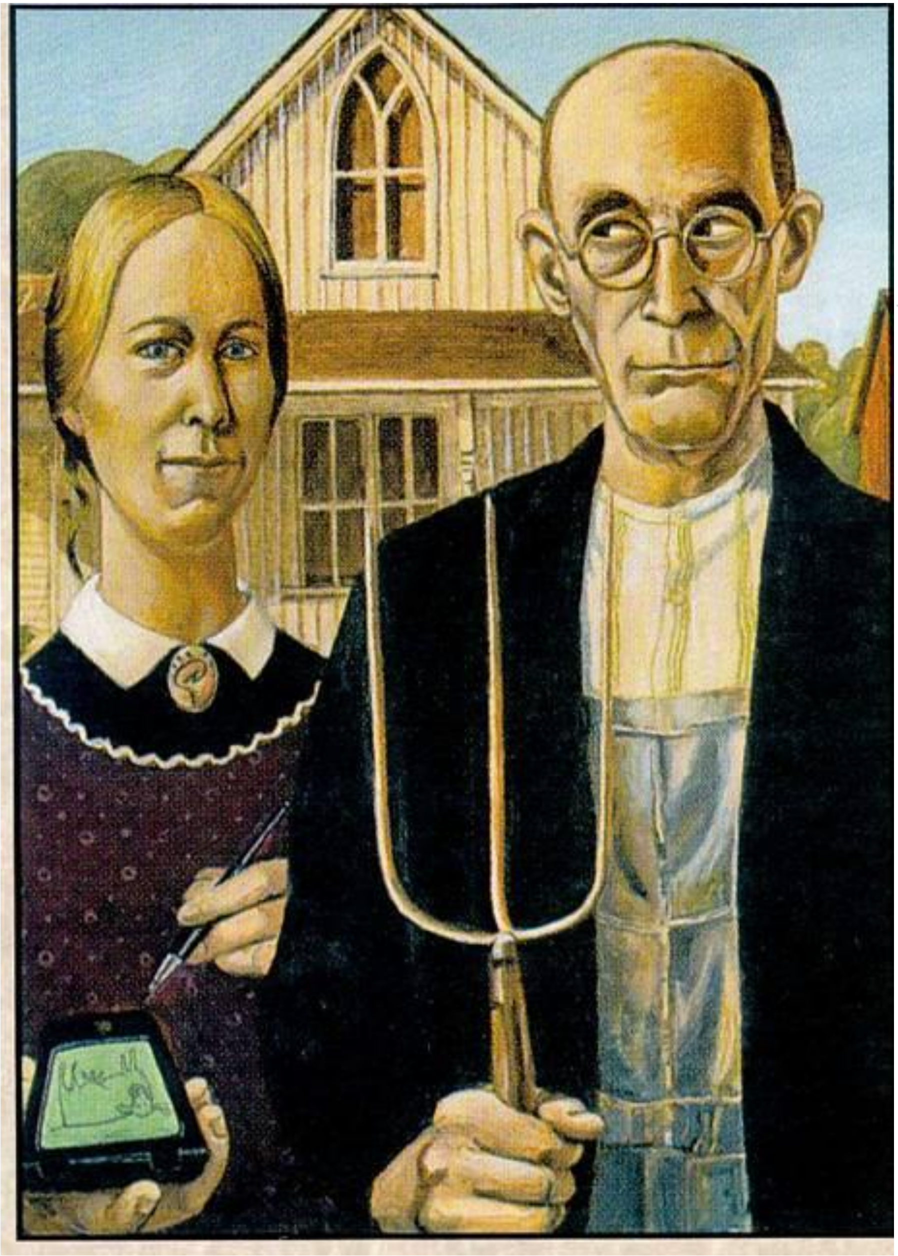
What are the advantages for fluids in high yield systems?

Sometimes you have to dig deep for the answers!

Dare to Dream!!



Source: AutoFarm Ad, ***Agricultural Technology/Irrigation***, October 2007



Thank You!!

Dr. Harold F. Reetz, Jr.
Director of External Support and FAR

International Plant Nutrition Institute
107 S. State Street
Monticello, Illinois 61856

Phone: 217-762-2074

e-mail: hreetz@ipni.org

IPNI