Nutrient Stratification When Inversion Tillage Goes Away: What Matters and What Doesn't

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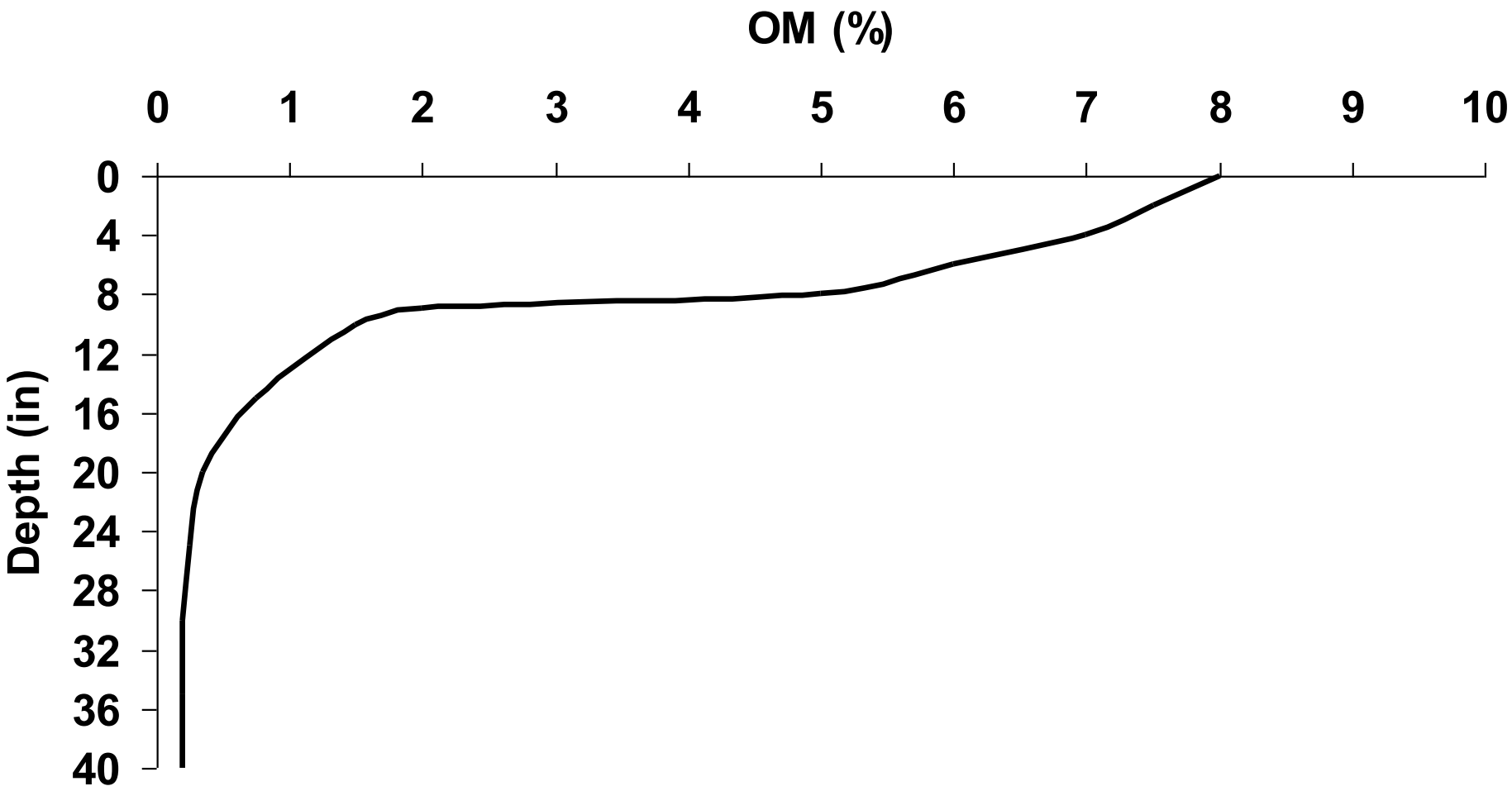
Less/Un-Disturbed Soils Exhibit Stratification

- Non-uniform distribution of soil physical, biological and chemical properties with depth.
- Result of natural processes. Before agronomic nutrient stratification there was 'natural' nutrient stratification due to nutrient 'upcycling'.
- The result of (soil) management decisions.
- Stratification increases as tillage depth/intensity decreases.

Soil Organic Matter in an Undisturbed Humid Region Grassland Soil



Stratified Soil Properties: Physical, Chemical, Biological

- Physical properties define the 'house' that sustains soil life;
- Chemical properties define the 'utilities' that sustain soil life;
- Microbes, vertebrates, invertebrates, plant roots = soil life;
- Soil chemical and physical properties create the soil 'health' environment for soil life below and above ground (yield).

Soil Physical Properties

- Inherent/Unchanging?
  - soil texture; primary particle size distribution (% sand, silt, clay)
- Dynamic/Changing?
  - structure/aggregation
  - bulk density/porosity
  - aeration/water holding capacity
  - heat capacity/temperature

Stratified Soil Physical Properties

Crop Rotation	Sampling Depth (in)	Sand %	Silt %	Clay %	Organic Carbon %	Bulk Density (g/cm^3)	Total Porosity %	GMD (mm)	Log GSD
CC		12.4	70.8	16.8	1.62	1.30	50.8	7.2	1.10
CS		12.2	69.0	18.7	1.67	1.31	50.7	10.3	1.16
CWS		13.0	69.6	17.4	1.56	1.34	49.5	8.2	1.09
		NS	NS	NS	NS	NS	NS	S	NS
	0 – 4	13.4	70.6	15.9	1.96	1.25	52.7	4.9	1.03
	4 – 8	11.7	69.0	19.3	1.27	1.38	48.0	12.2	1.20
		S	NS	S	S	S	S	S	S

GMD= Geometric Mean Diameter
log GSD=Logarithm of Geometric Size Distribution
NS = Not Significantly Different at the 90% Level of Confidence
S = Significantly Different at the 90% Level of Confidence

Soil Physical Properties

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Surface Soil Structure

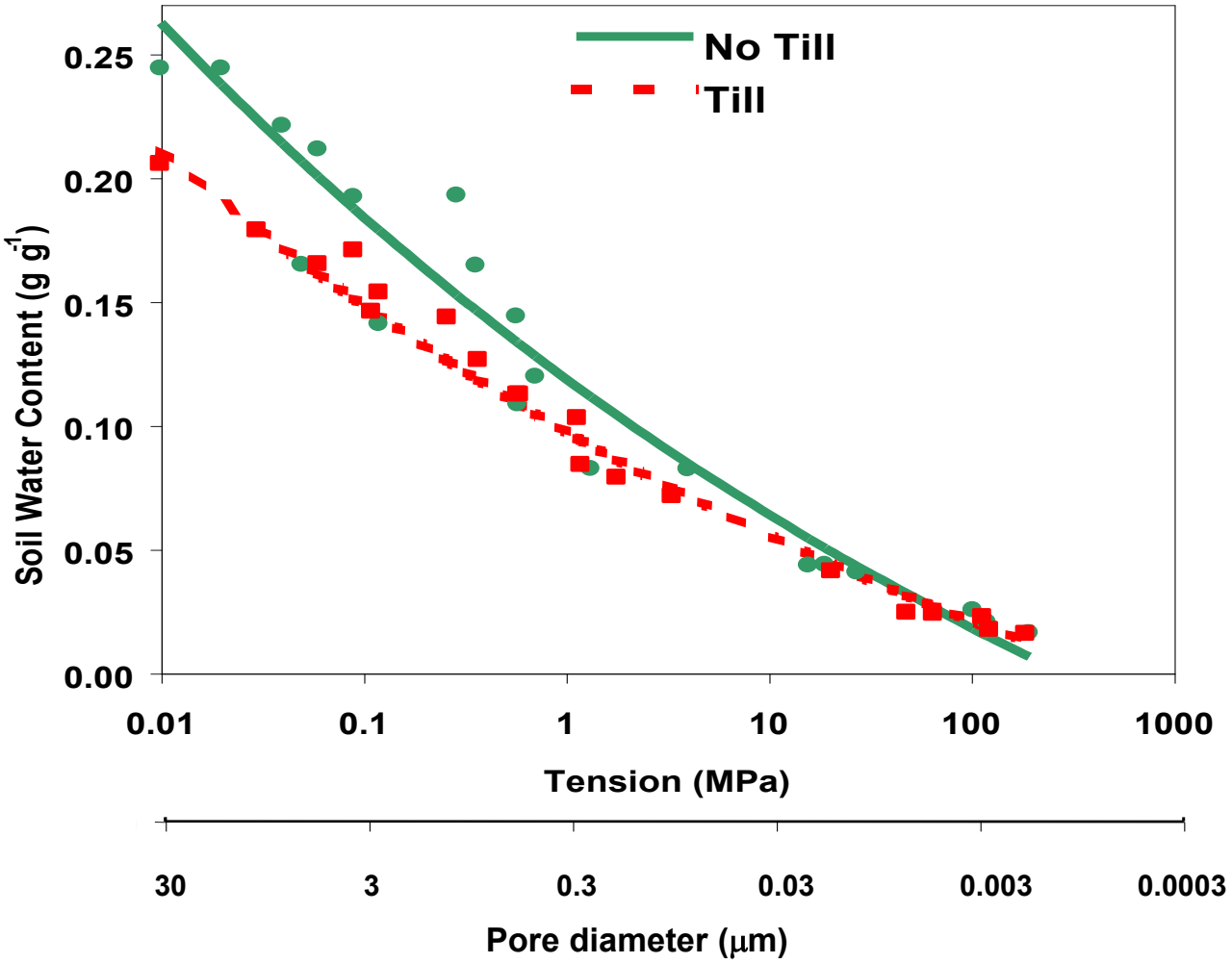
- Abundance of porosity for water infiltration and root function
  - penetration/exploration
  - aeration/oxygen diffusion
  - water holding capacity
  - stability

Both have porosity, but which has structure?

Which will better resist outside forces?

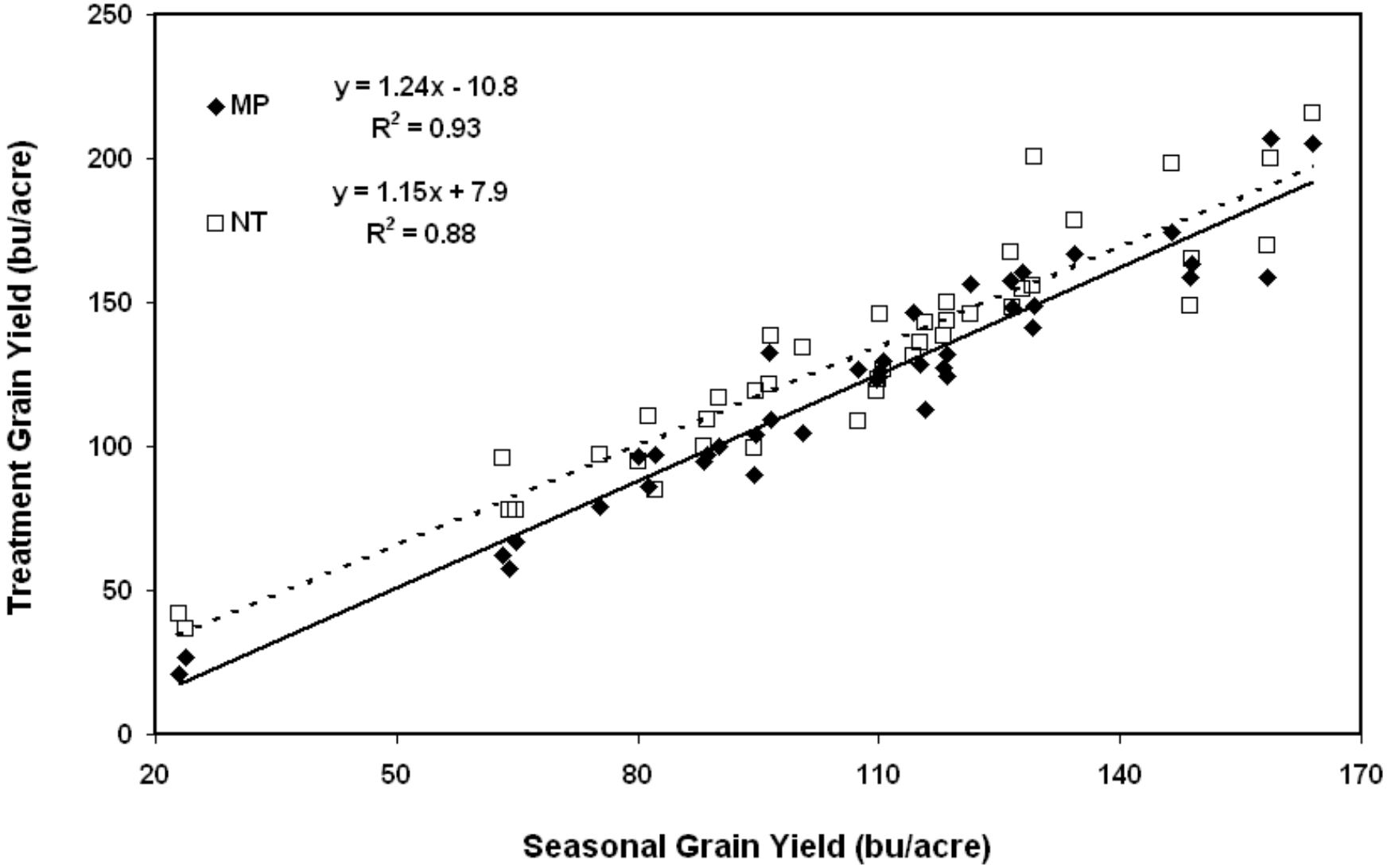
Chemical analysis would find no differences here. Structure adds utility/function not measured by chemistry.

Soil Water Availability: More Porosity With No-Tillage



What's A Little Extra Porosity Worth?

- 2 to 4 more days without wilting between rainfall events.
- More days without wilting means more yield, especially in drier years.


Corn Yield @ 150 lb N/Acre vs. Seasonal Average Yield
Treatment Grain Yield (bu/acre)
Seasonal Grain Yield (bu/acre)
MP
NT
y = 1.24x - 10.8
R2 = 0.93
y = 1.15x + 7.9
R2 = 0.88
250
200
150
100
50
0
20
50
80
110
140
170

Soil Structure - Aggregation: Start With A Shovel

Good structure: Soil accepts water, retains water, delivers water and oxygen.
Provides good home to roots and other soil biology.

Lots of lateral, but less downward, root growth. 'Platy', layered look to the bulk soil volume. Will be dense and slow to accept/'perc' water.

photo by Chad Lee

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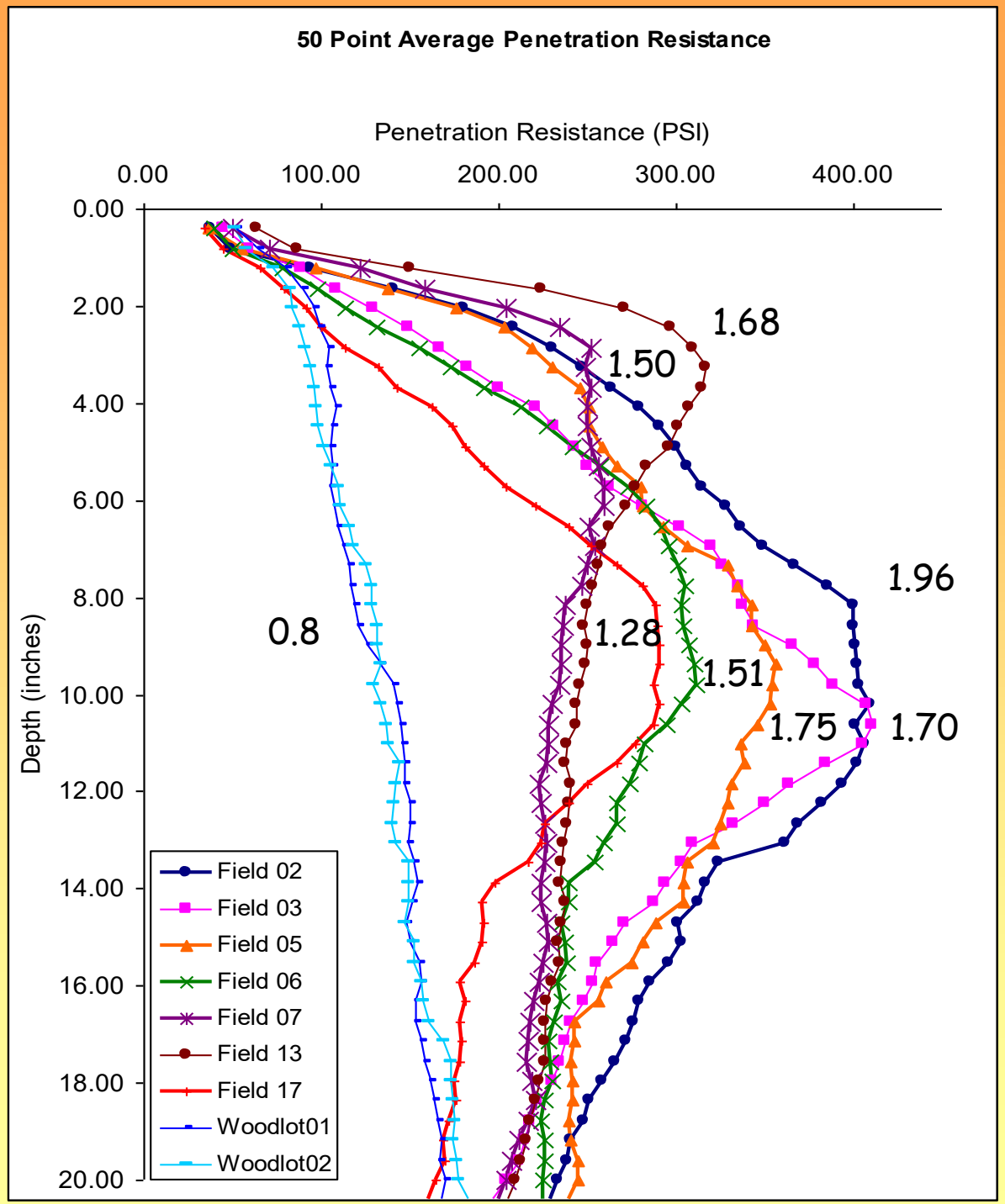
Soil Compaction Is Stratified



Using Penetration Resistance:

250-300 psi should trigger action.

Note different depths, some fields have a problem at 2-4 inches, others at 8-12 inches.

Compaction Impacts

Greater density, lower porosity, reduced infiltration, greater ponding time and/or runoff.

Less aeration – oxygen and/or more erosion.

Long-Term NT Resists Compaction Subsoiling Can Make Things Worse

2009 Soybean Yield – bu/ac

Treatment	Compaction	Tillage	Harvest Population	Yield Bu/acre
1	None	No-till	185,600	54.8 A
2	None	Fall Subsoil	179,200	53.9 A
3	10 ton	No-till	153,600	51.6 A
4	10 ton	Fall Subsoil	166,400	45.6 B
5	20 ton	No-till	163,200	52.0 A
6	20 ton	Fall Subsoil	185,600	39.0 C
				LSD (.05) 4.19

Soybean yield was not reduced by increasing traffic weight, and was reduced by subsoiling.

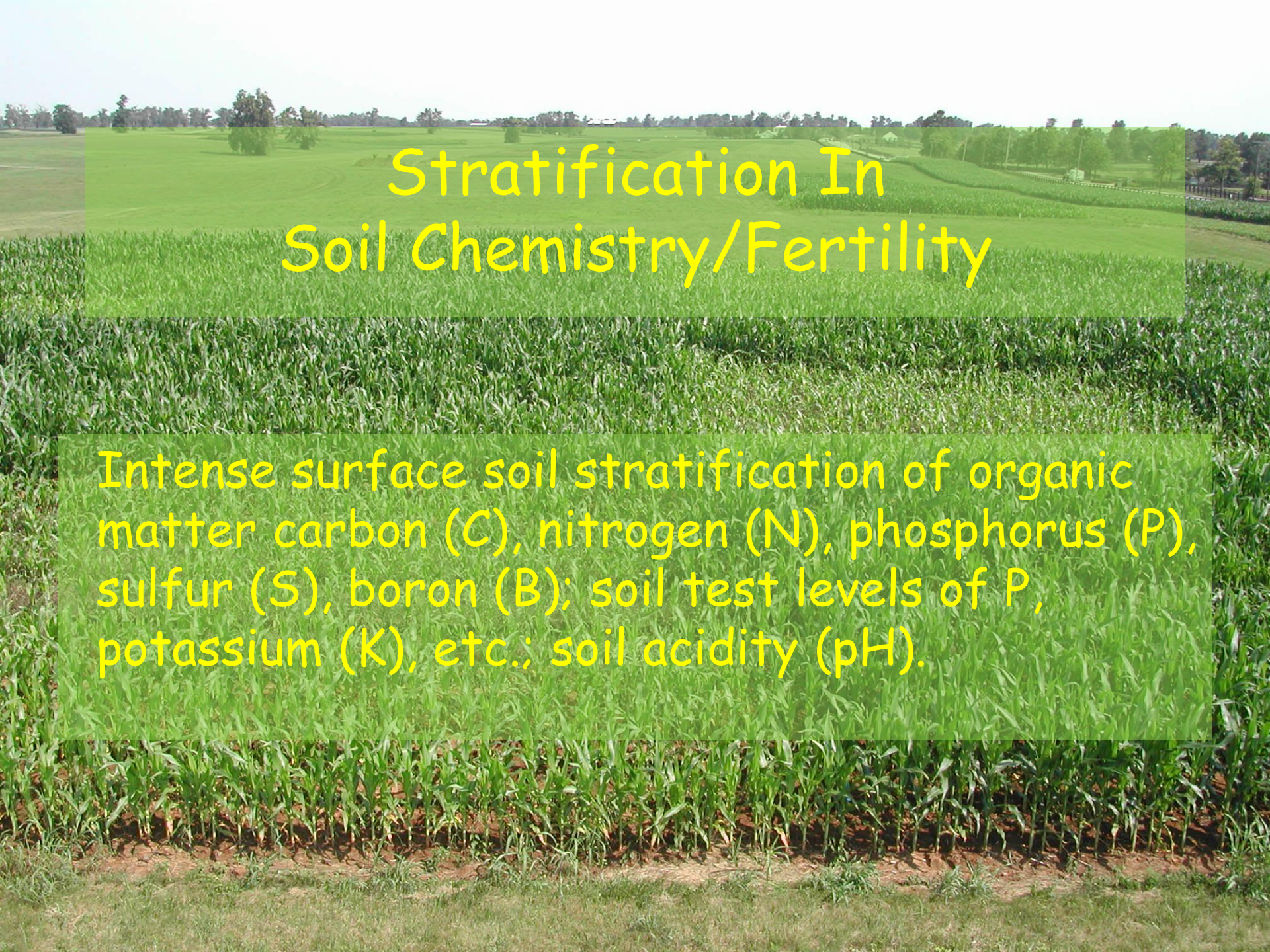
No-Tillage & Compaction

Not a panacea --- you do little tillage, but can still have planter and harvest traffic issues

No-tillage does tend to 'build' soil structure

Stable structure built with continued biological activity *and* soil organic matter

Roots, worms, continuous cropping (including cover crops), and no-tillage (to minimize disturbance of macroaggregates, fungal hyphae networks, worm and root channels)



Stratification In Soil Chemistry/Fertility

Intense surface soil stratification of organic matter carbon (C), nitrogen (N), phosphorus (P), sulfur (S), boron (B); soil test levels of P, potassium (K), etc.; soil acidity (pH).

How might soils get this way?

Remember 3 soil health principles:

Reduced soil disturbance,
especially no-tillage

Increased crop intensity,
continuous living cover

Increased use of organic materials as nutrient sources,
and most are surface applied


Most Manure/Organic Amendments
Are Surface Applied

Continuous Living Cover

- Heightens nutrient cycling up to the soil surface
- Generally, without nutrient removal by added species
- Nutrient stratification usually reinforced

Changes in Mehlich III P with Depth and Time after Sod Insertion in Rotation:

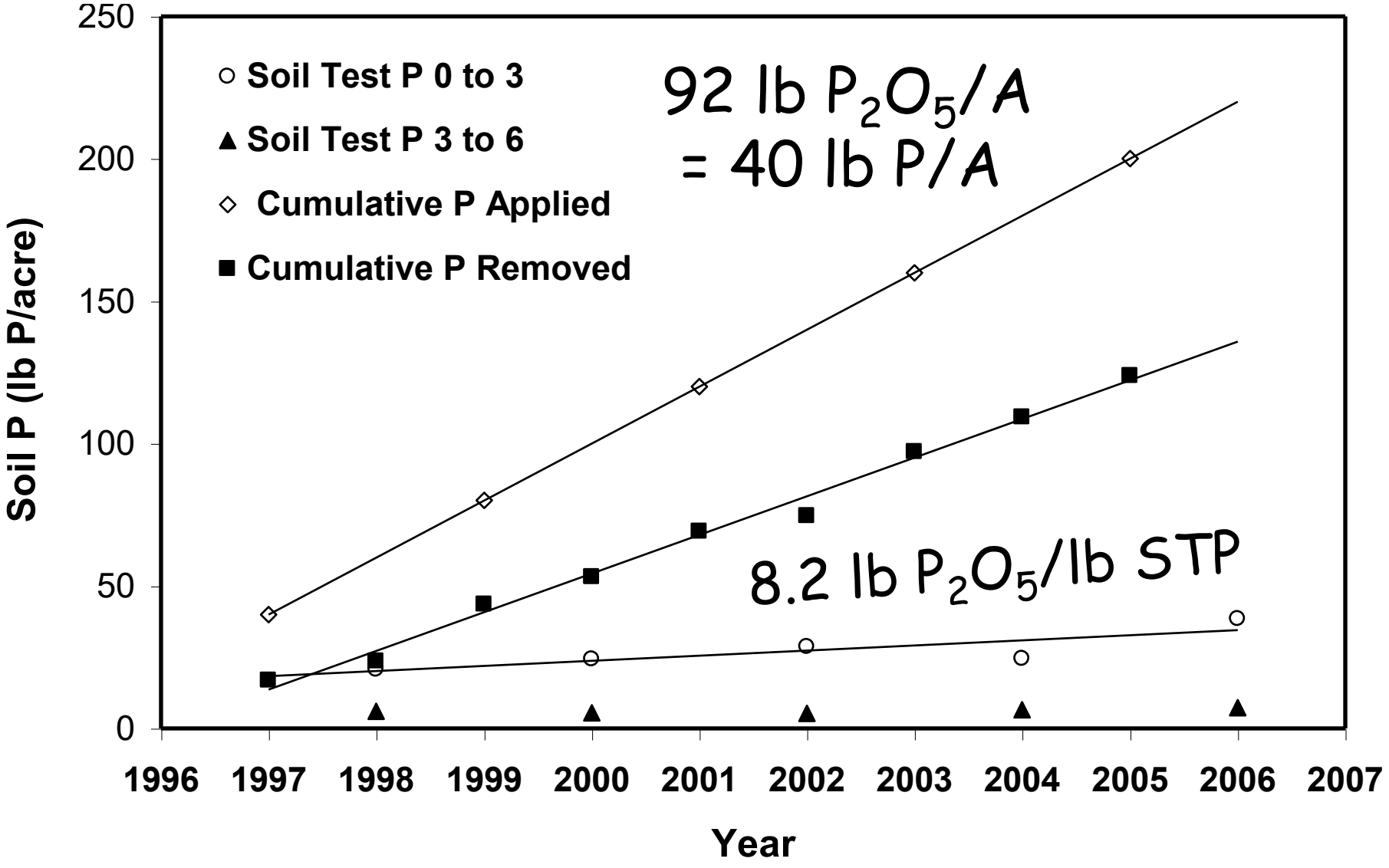
Year	Soil Test P 0-5 cm ppm	Soil Test P 5-10 cm ppm	Soil Test P 10-20 cm ppm
0	36.8	26.8	11.4
1	35.8	29.9	11.0
2	68.3	45.2	14.1
3	87.2	54.4	20.1

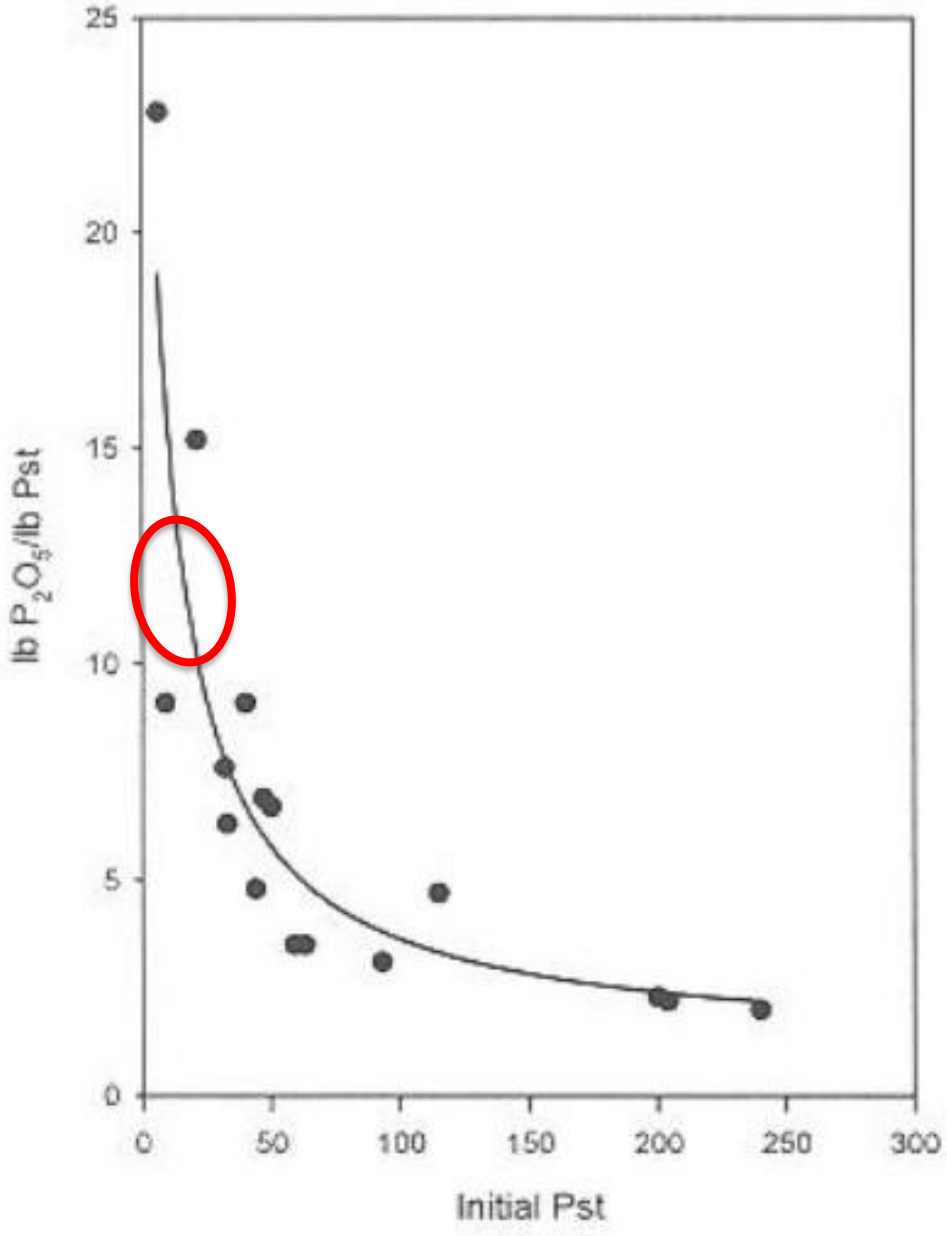
Pena-Yewtukhiw et al. (SSSAJ: 2017)

NT Soil Chemistry/Fertility

- Lower fixation potential due to greater organic matter – K (SOM CEC holds K weakly)
- Lower fixation potential due to greater organic matter – P (and also weaker adsorption to clay at now higher soil P levels)

Soil P Dynamics @ 92 lb P_2O_5/A



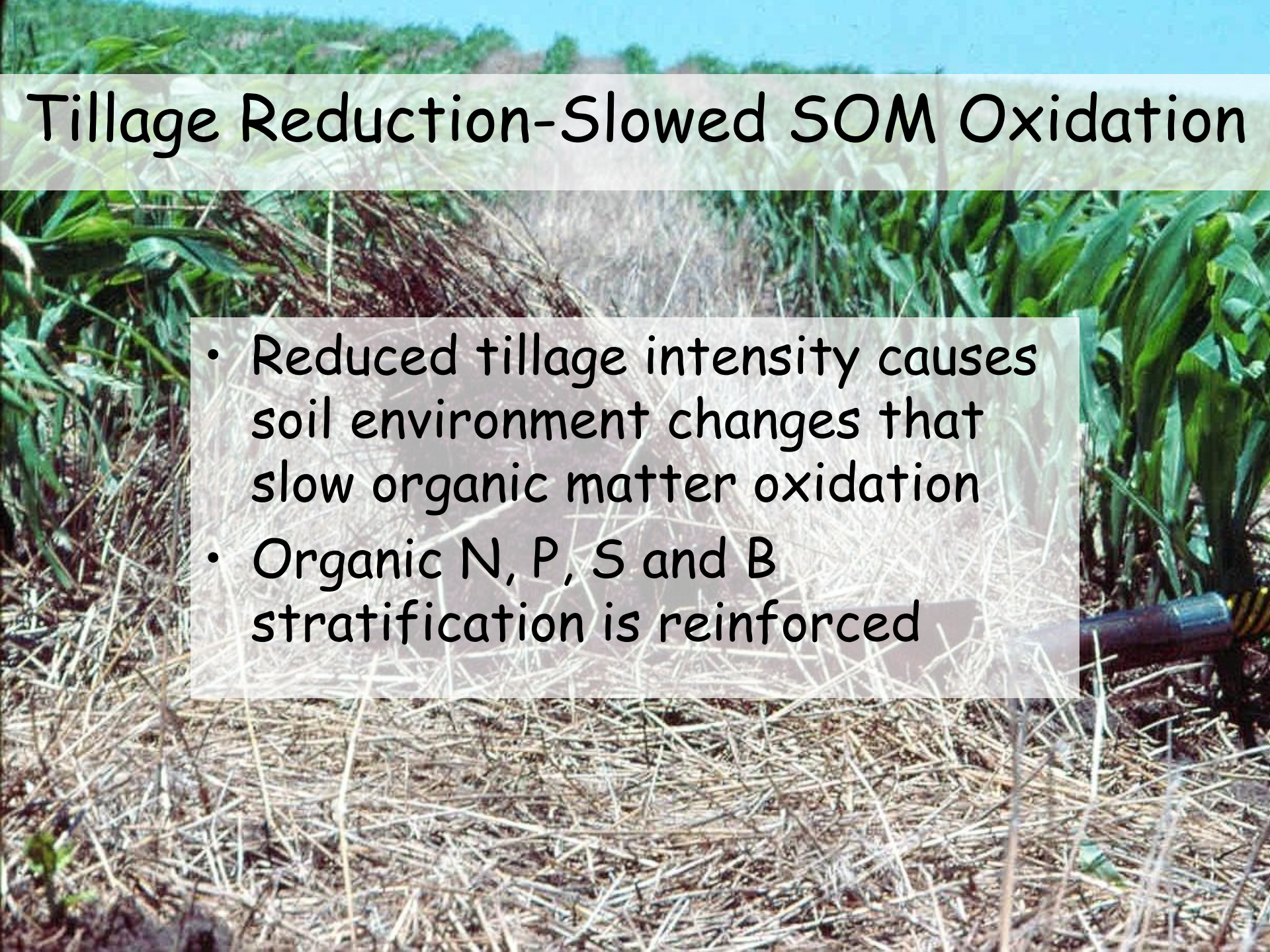


The lb P_2O_5/A required to change MIII soil test P by 1 lb/A: as related to the initial soil test P level – after an 8-week lab incubation.

10-12 lb P_2O_5 per lb STP

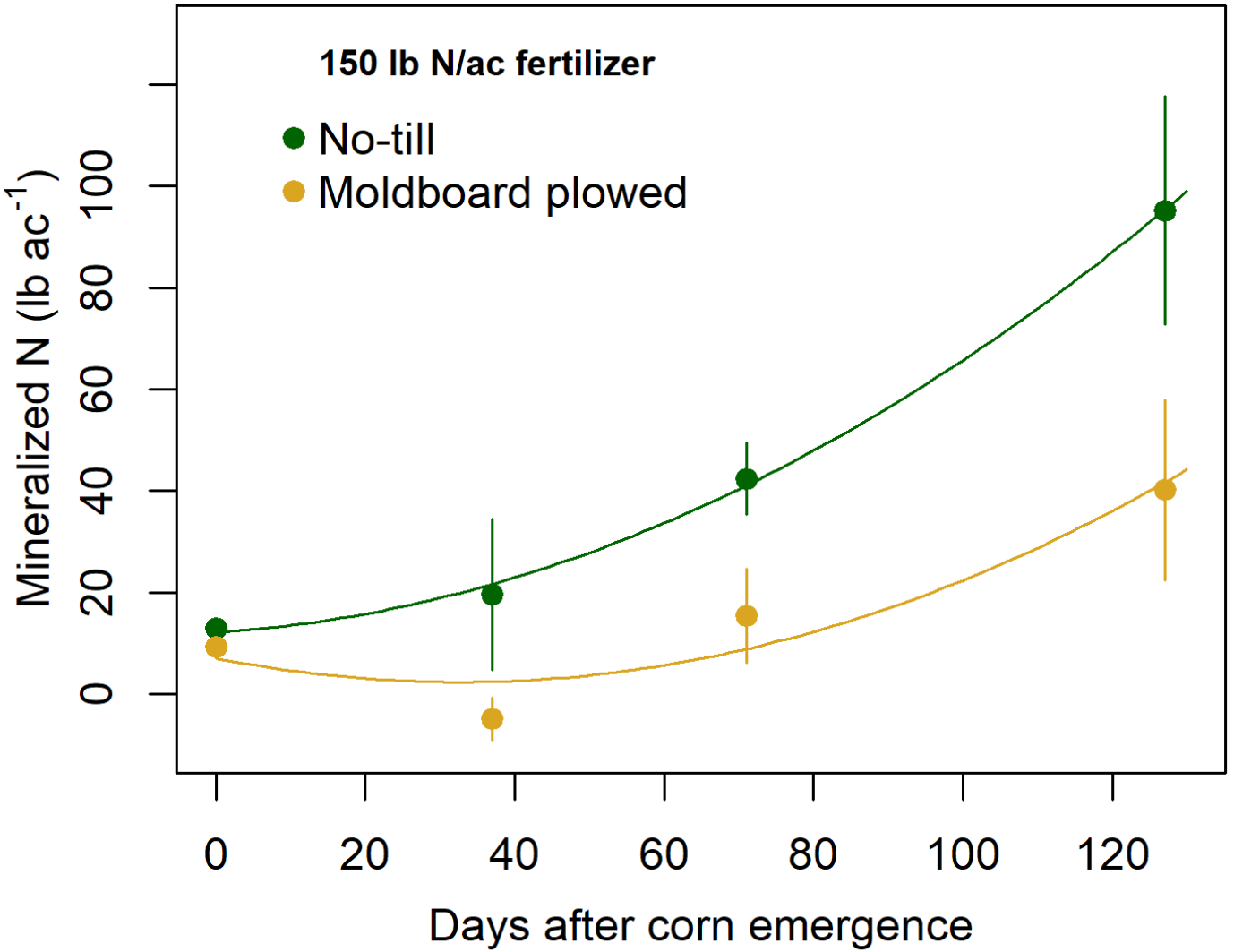
Thom and Dollarhide, 1987

Tillage Reduction-Slowed SOM Oxidation

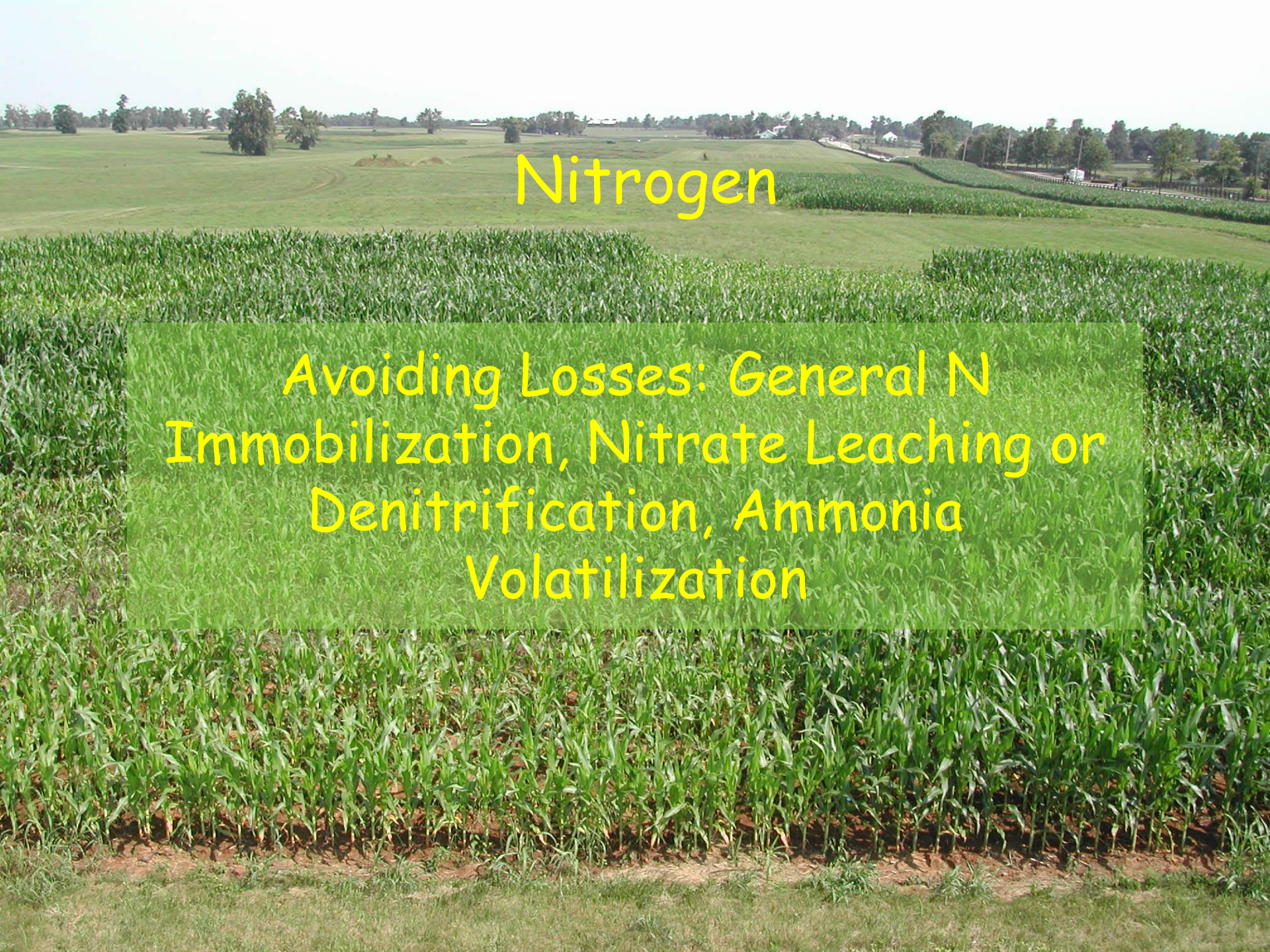


- Reduced tillage intensity causes soil environment changes that slow organic matter oxidation
- Organic N, P, S and B stratification is reinforced

Higher OM NT Soil Mineralizes More N



Poffenbarger et al., unpub


Nitrogen
Avoiding Losses: General N Immobilization, Nitrate Leaching or Denitrification, Ammonia Volatilization

Tillage Reduction-Cooler/Wetter Soils

- Cooler soil environment slows biological activity
- Wetter soils – less aeration – less oxygen – shifts in the aerobic microbial communities.

NT's Soil N Biology

More surface plant residues; more stratification of soil microbiology; more stratification in N's biologically driven transformations

Shift towards more anaerobic, less aerobic (less oxidative, more reductive)

More N immobilization, denitrification, leaching, volatilization losses; slower N mineralization and nitrification

Reducing N Immobilization And/or Urea-N Volatilization: Placement Below The Surface

N Placement for NT Corn After Corn

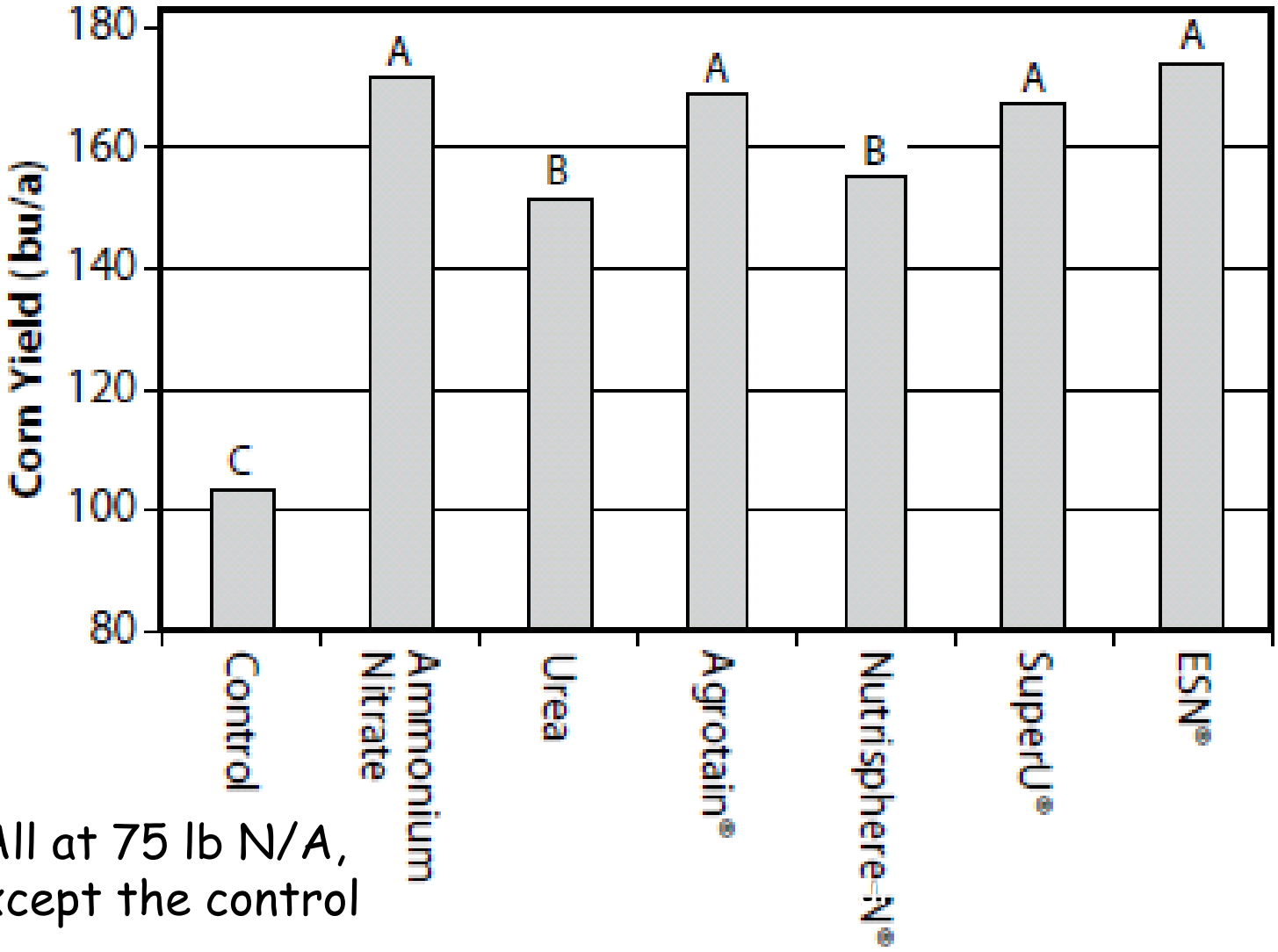
	----------UAN----------			
N Rate lb N/A	broad-cast	surface band	injected	N Rate average
	NT corn after corn yield (bu/A)			
80	89	118	125	111
160	108	133	141	127
240	114	138	154	136
Placement average	104	130	135	

Adapted from Touchton and Hargrove, 1982

Inhibit Urea N Loss -> Delayed N Success

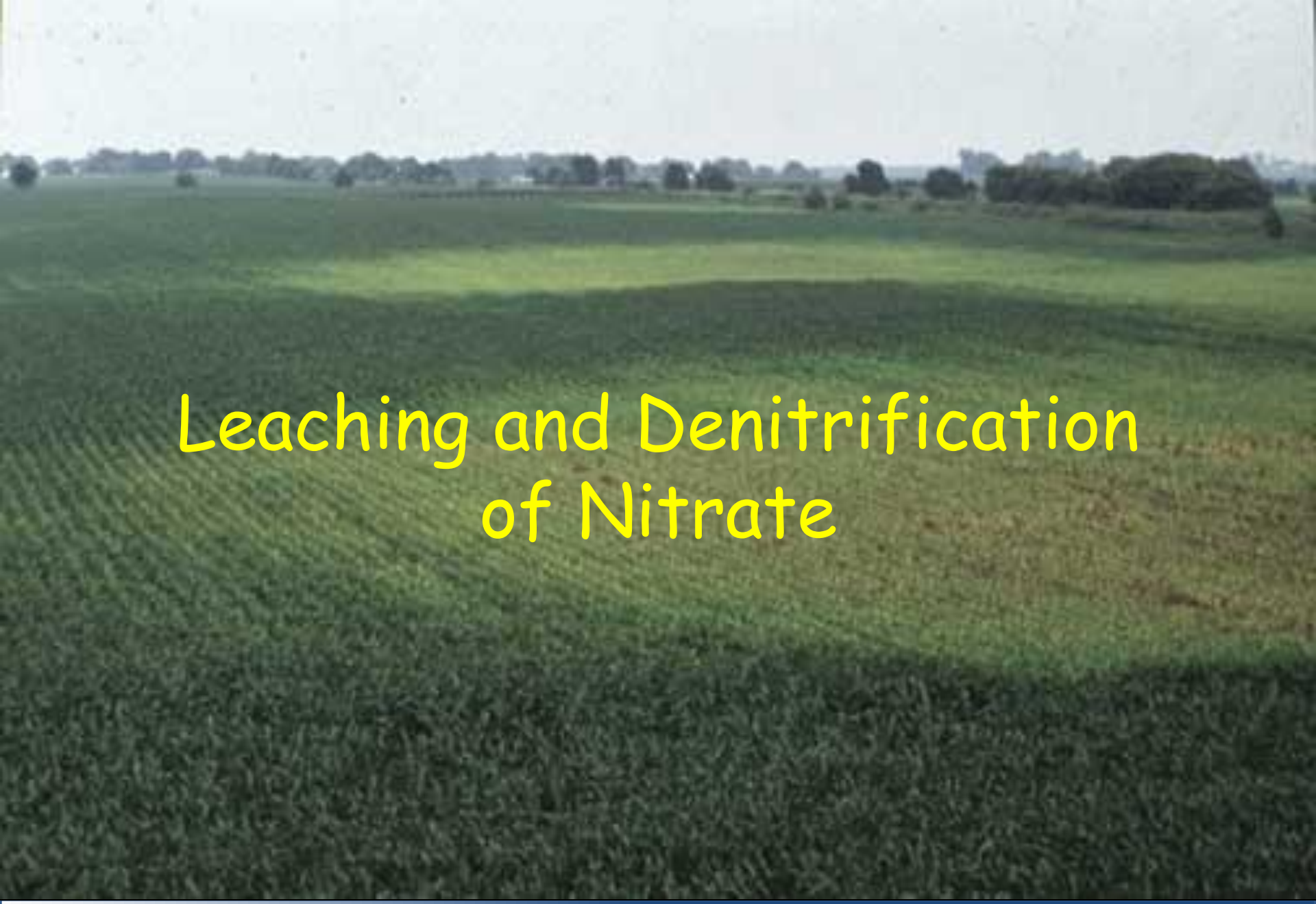
Urease Inhibitors & Polymer Coated Urea

Make Urea Use In Delayed N Applications Work Better



All at 75 lb N/A, except the control

Murdock & Schwab, 2010

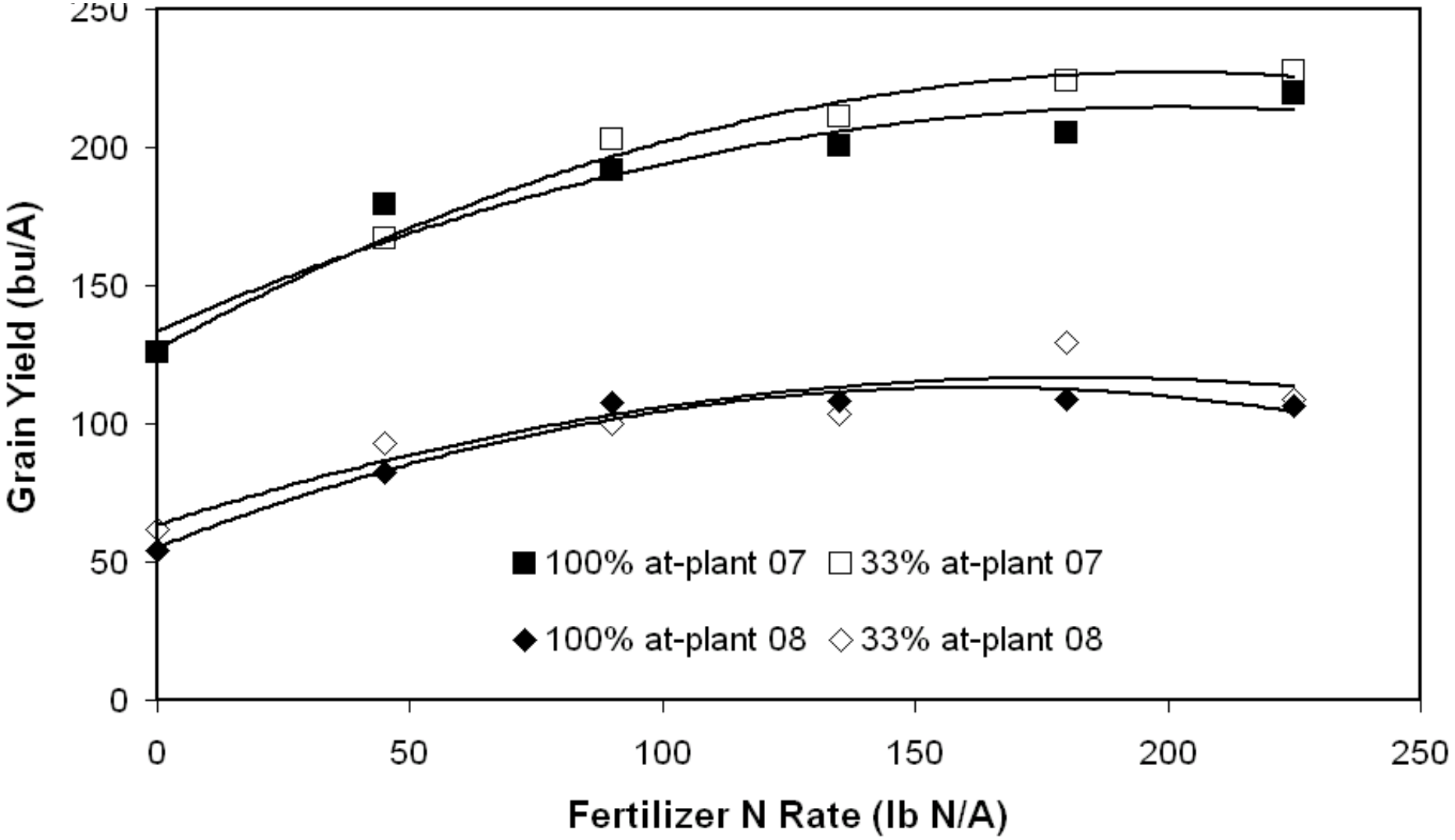


Leaching and Denitrification of Nitrate

UKAg Department of Plant and Soil Sciences

John Sawyer, Iowa State University

Wet Soil/Wet Spring – Split/Delay N



Use Nitrification Inhibitor

courtesy of Greg Schwab

Take-Home on N Inhibitors/Stabilizers

Inhibitors are needed on some fields in all years; more fields in some years

Know the field, know the N management situation, educated guess the season

There are alternatives (placement, split/delayed application) to the N inhibitors, enhance efficiency products – may be cheaper, more doable (or not)


So, Is Stratification
Hurting Crop Nutrition?

It Can:
Acidity, Alkalinity, Salinity

All three of these can be detrimental if allowed to remain/stratify near the surface.

Acidity in Reduced Tillage Soils

- No-tillage – no mixing of soil
- This can cause an "acid roof"
  - √All residue mineralization, legume mineralization, fertilizer N acidification generally occurs at point of contact/application – the surface

Soil pH and Tillage: Before and After 10 yr Corn at 150 lb N/acre/yr

crop and tillage	soil depth	organic Carbon	soil pH
	inches	%	
unamended sod	0-2	3.8	5.8
	2-6	1.7	6.1
	6-12	0.9	6.3
corn/NT	0-2	2.8	4.8
	2-6	1.4	5.6
	6-12	0.7	6.2
corn/MP	0-2	1.4	5.8
	2-6	1.3	5.9
	6-12	0.7	6.2

Blevins et al. (1983)

Lime Placement?

Most lime is surface broadcast

Downward movement of the lime reaction is slow (lime reaction is itself slow)

However, timely liming successfully controls soil acidity, without tillage, in NT fields

Soil pH Under No-Till Corn Before And After Liming

Soil Depth inches	Initial*	Check** no lime	Limed** 4.5 ton/A
0-2	5.7	4.6	6.4
2-4	5.7	5.5	6.4
4-8	5.5	5.5	5.9
8-12	5.1	5.1	5.2

* Beginning of Study ** After 5 years

Murdock and Blevins, 1978

Acid Surface Soil and Agri-Chemical Activity

Acid surface soil can reduce triazine activity

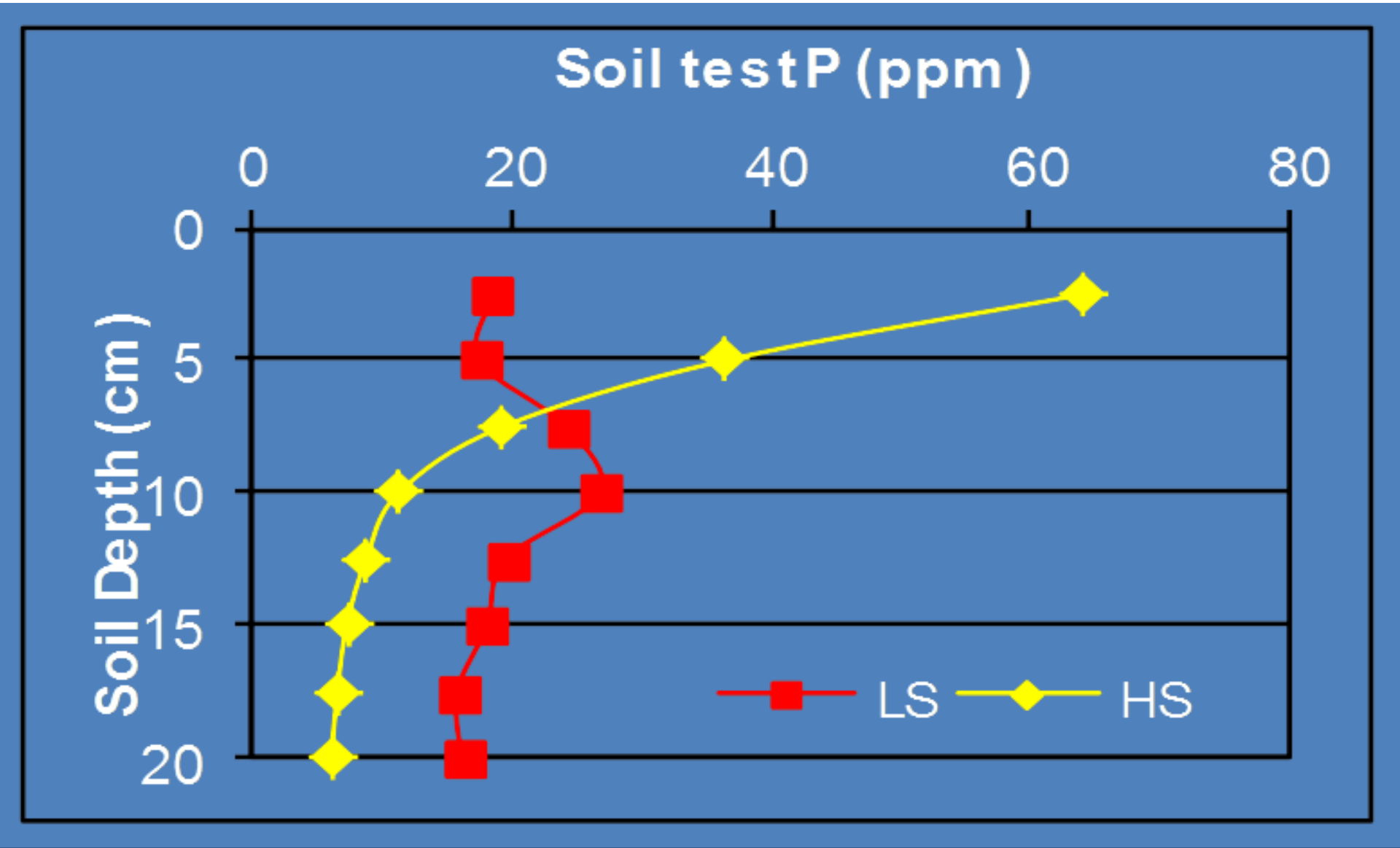
Acidity can deactivate NBPT, an otherwise effective urease inhibitor

Take-Home on Liming Stratified Acidity

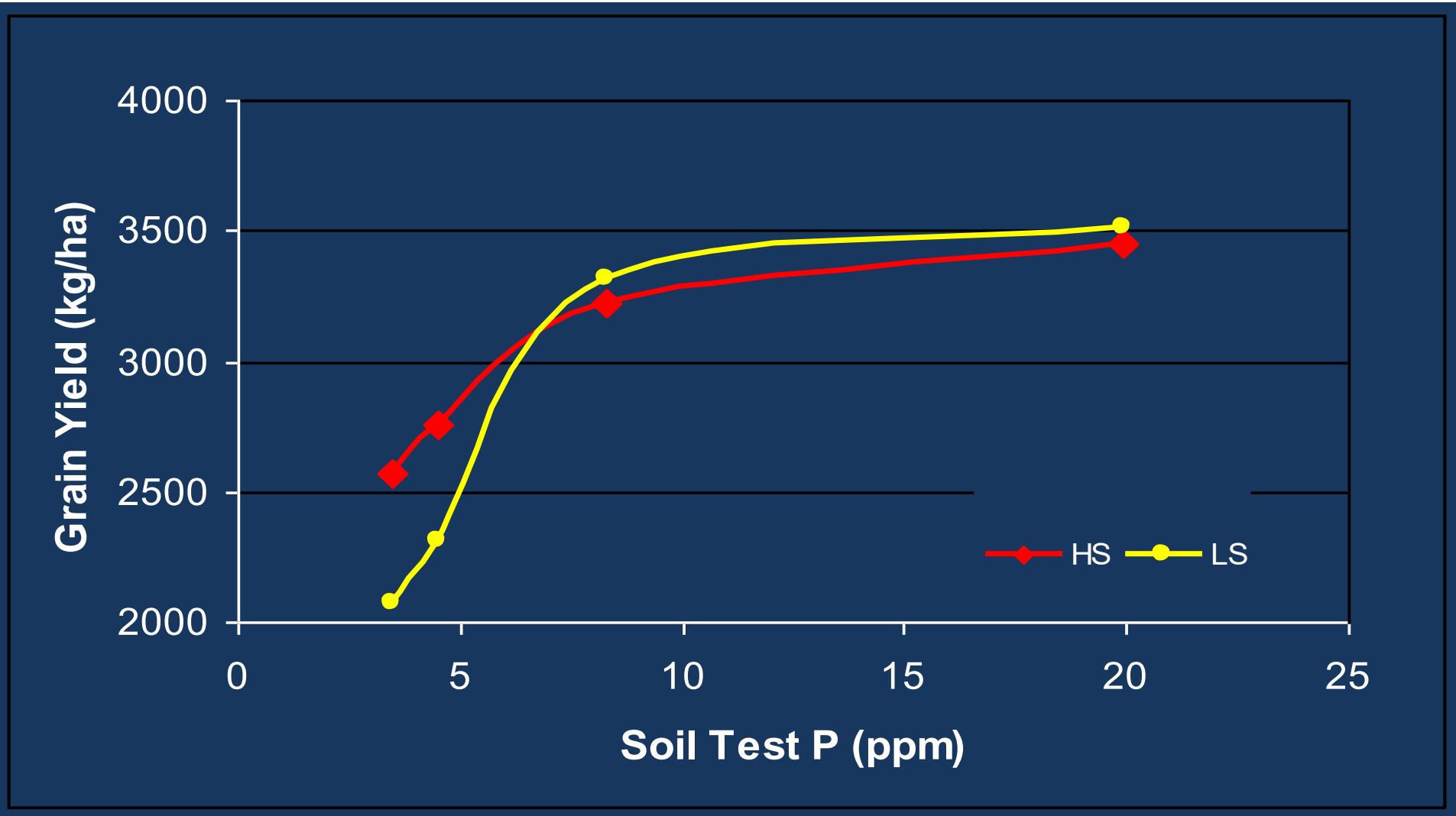
- Stratified soil acidity can be managed without tillage
- The lime reaction is sufficiently mobile so as to adequately raise pH in the surface few inches of no-till soils
- Lower lime rate per application, but lime more often
- Sample carefully (shallow – 0 to 2 in)


Crop Response To P and K
Stratification

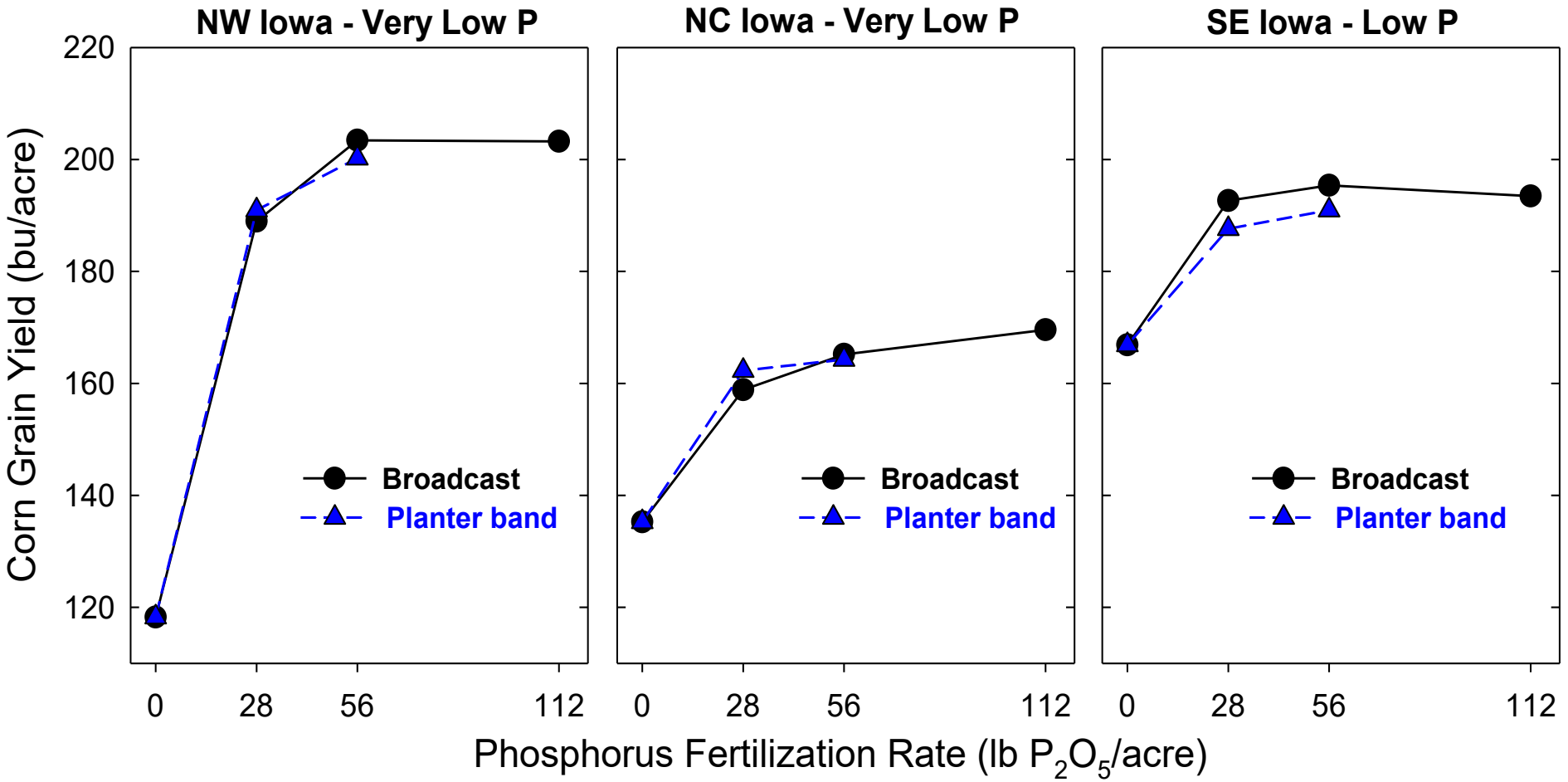
Stratification of Mehlich III P
Average (both) = 20 ppm STP



Interaction of P stratification and soil test P level on soybean yield



Phosphorus for No-Till Corn



In NT fields, no greater efficiency with banded P?

Mallarino, 2010 courtesy Bruulsema, 2013

Corn K Nutrition & Stratification

The vertical distribution of soil test K and K uptake by corn grown in two tillage systems.

	increment soil test K		interval soil test K				corn K uptake	
depth increment	no-till (NT)	plowed (MP)	depth interval	no-till (NT)	plowed (MP)	ratio NT/MP	year	ratio NT/MP
inches	ppm		inches	ppm				
0 to 2	170	132	0 to 2	170	132	1.29	1980	1.35
2 to 6	104	113	0 to 6	126	119	1.06	1981	1.25
6 to 12	86	95	0 to 12	105	107	0.99	average	1.30

Blevins et al. (1986)

Root Growth Response to Zone Enrichment

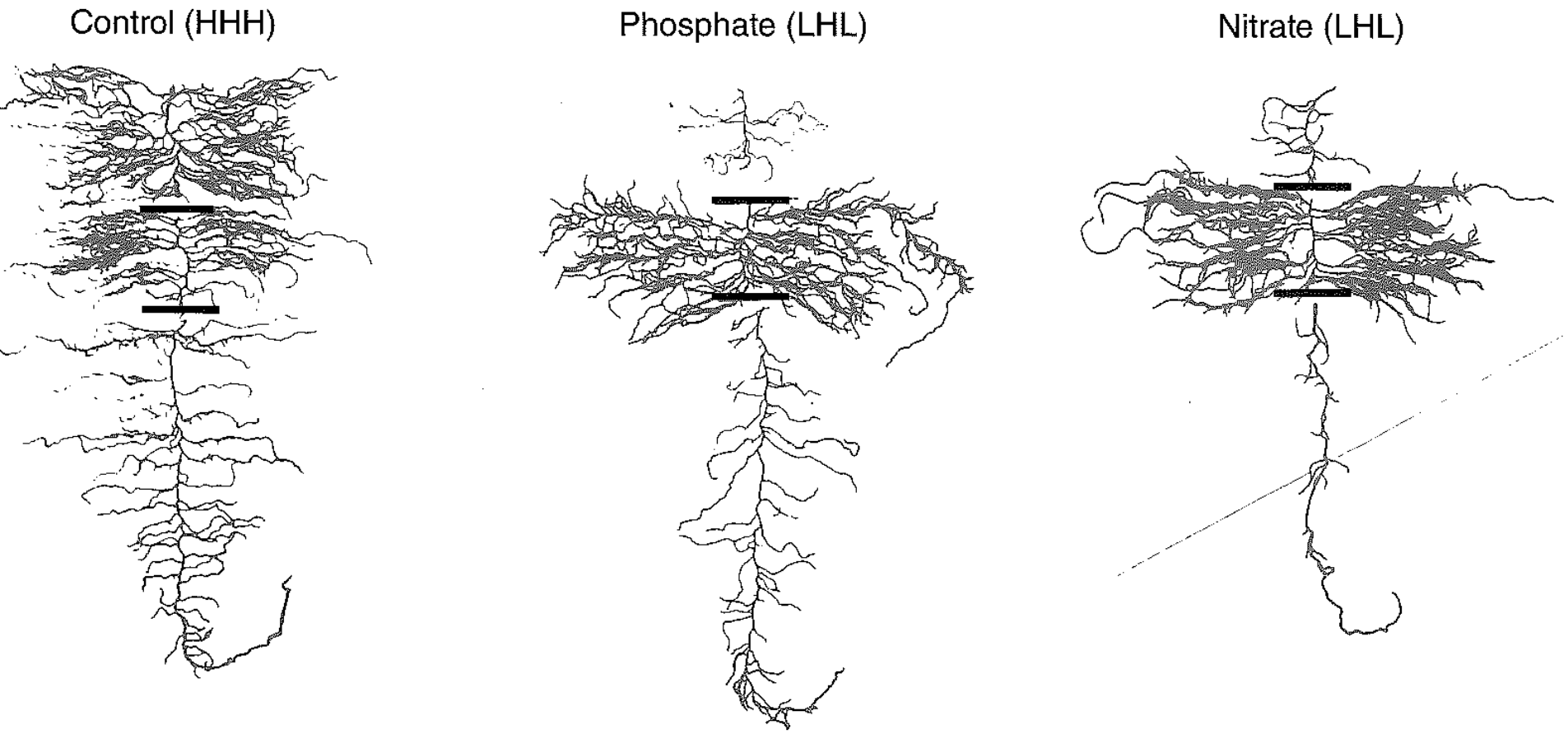
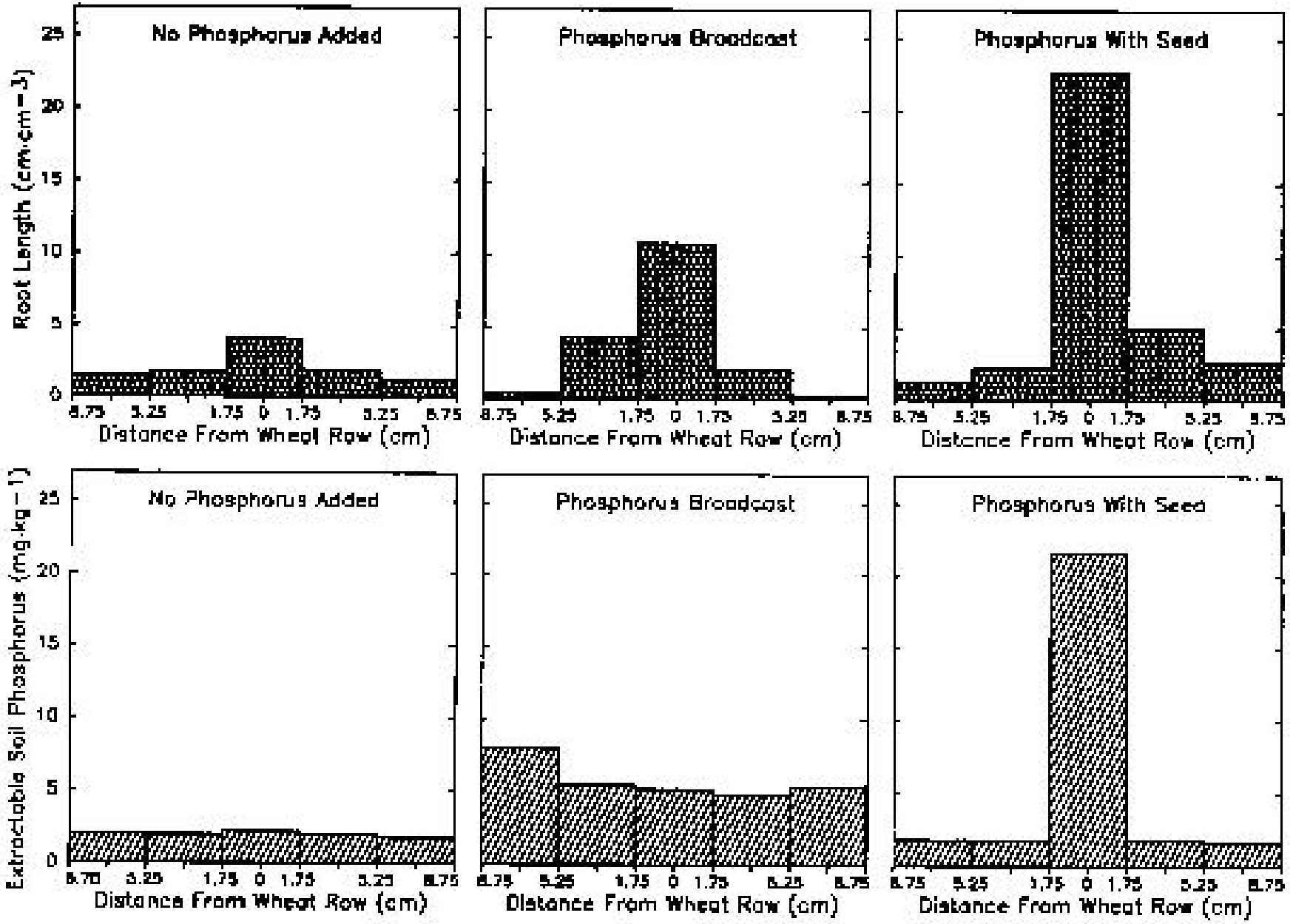


Fig. 5-4, Havlin (2014)



Matar and Brown, 1989 courtesy Black, 1994


If You Don't Mix It,
You Don't Fix It


Stratification brings together roots, water, mulch, and nutrients:
In the same way that plants have evolved to use those resources

Nutrition Summary

- In and of itself, stratification not an issue for crop nutrition
- Greater crop diversity, whether by insertion of cover crops or other grain - sod crops into the rotation, will likely require more soil nutrition science and 'experiential learning'
- Green/manure organic sources will complicate available nutrient prediction, but not greatly

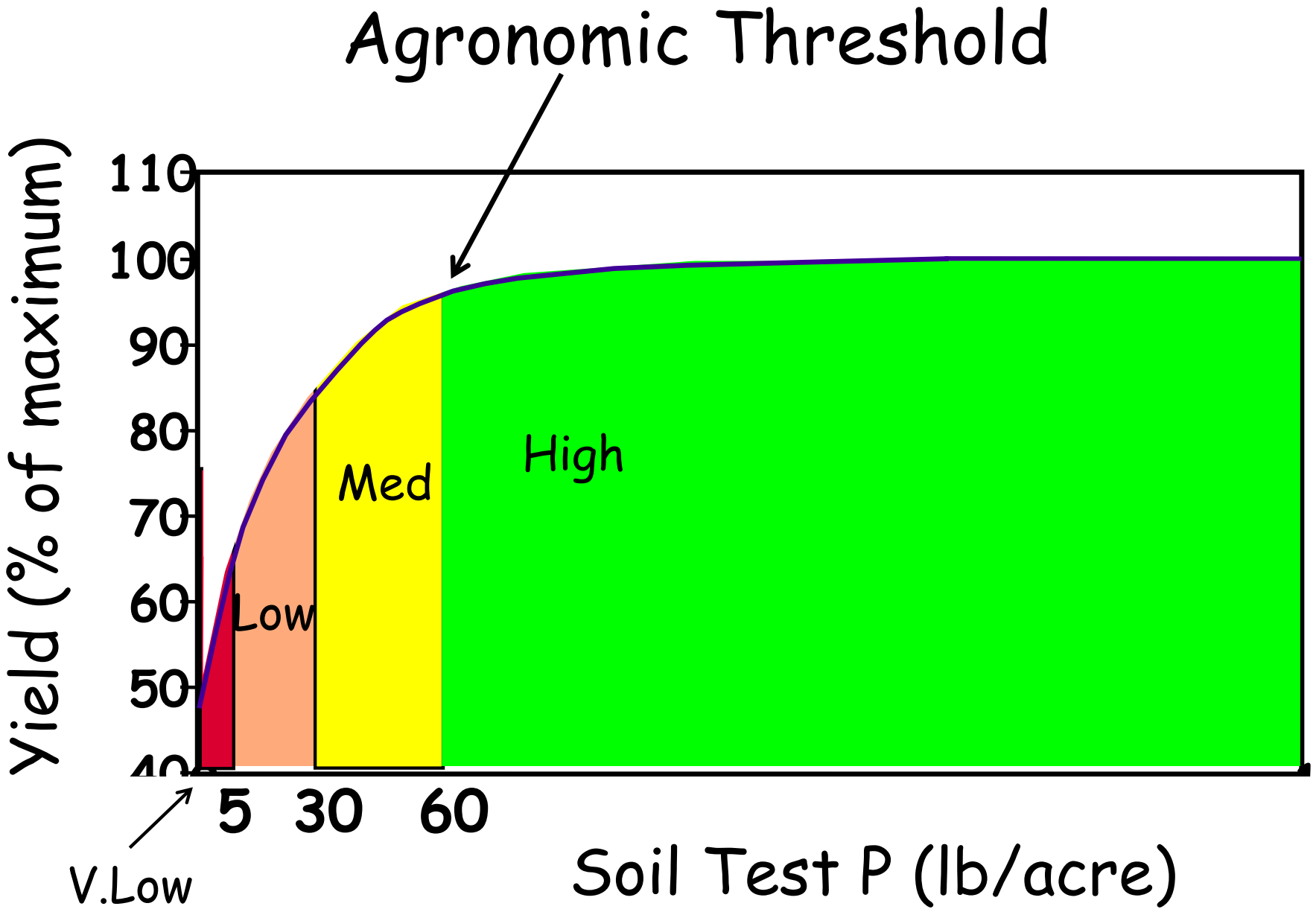
Environmental Challenges – Stratified P

P management is being driven, in part, by environmental considerations. Why?

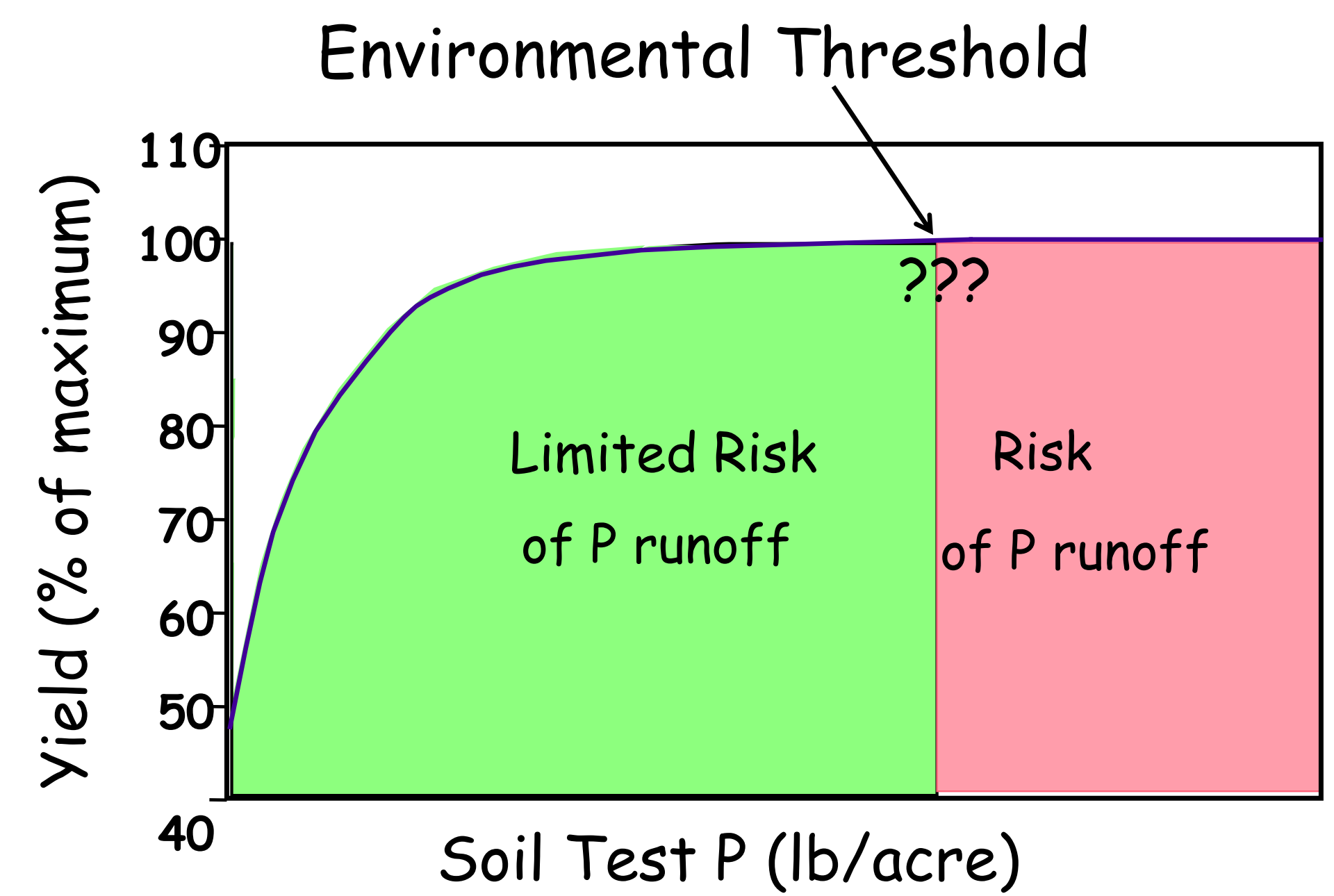
Place P below the soil surface, keeping P away from moving surface runoff water.

Cover crops can help with P uptake, but crop death cycles nutrients to surface.

Keep P rates agronomically relevant.

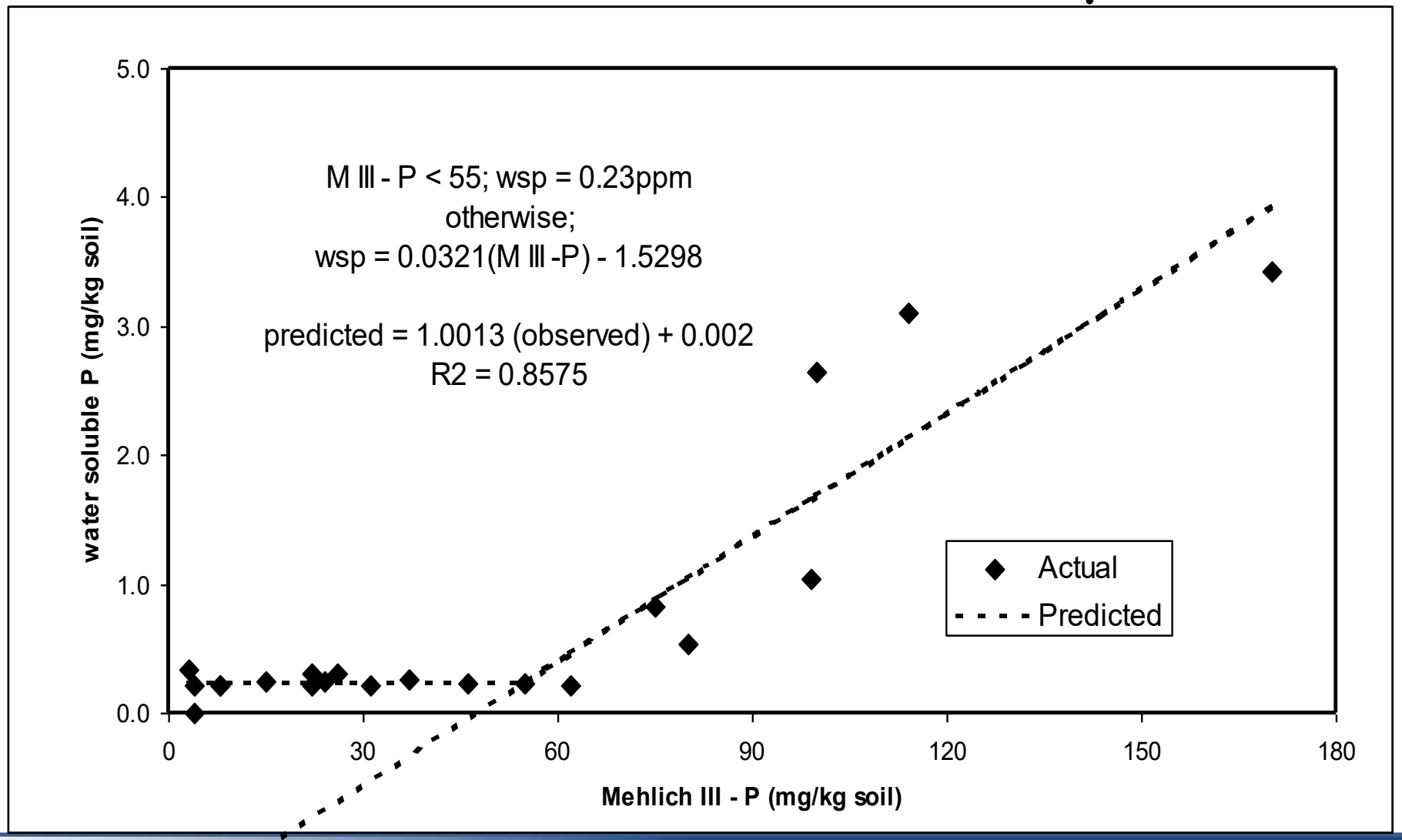


courtesy Frank Sikora



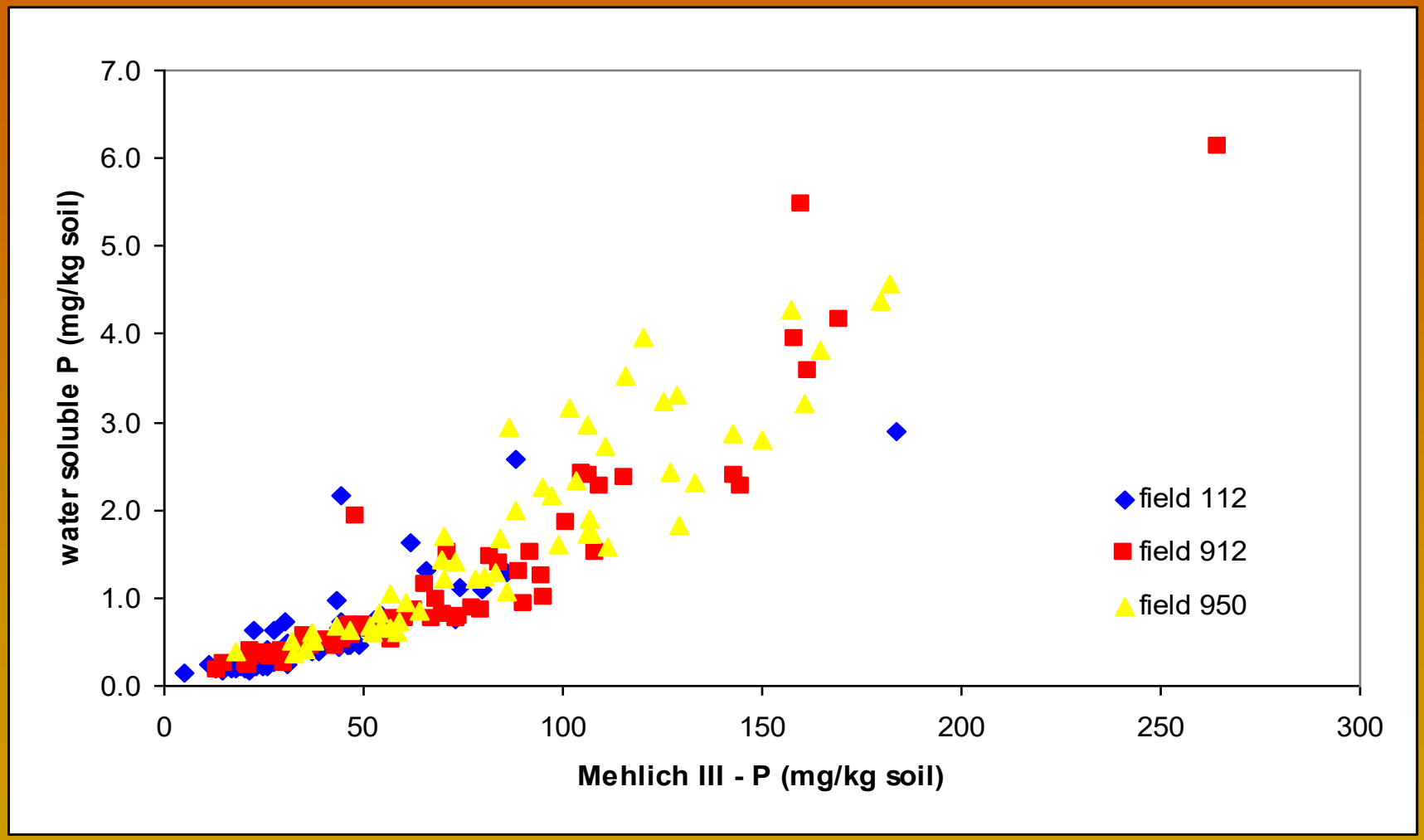
courtesy Frank Sikora

Predicting Water Soluble P from Mehlich III P on 20 Kentucky Soils

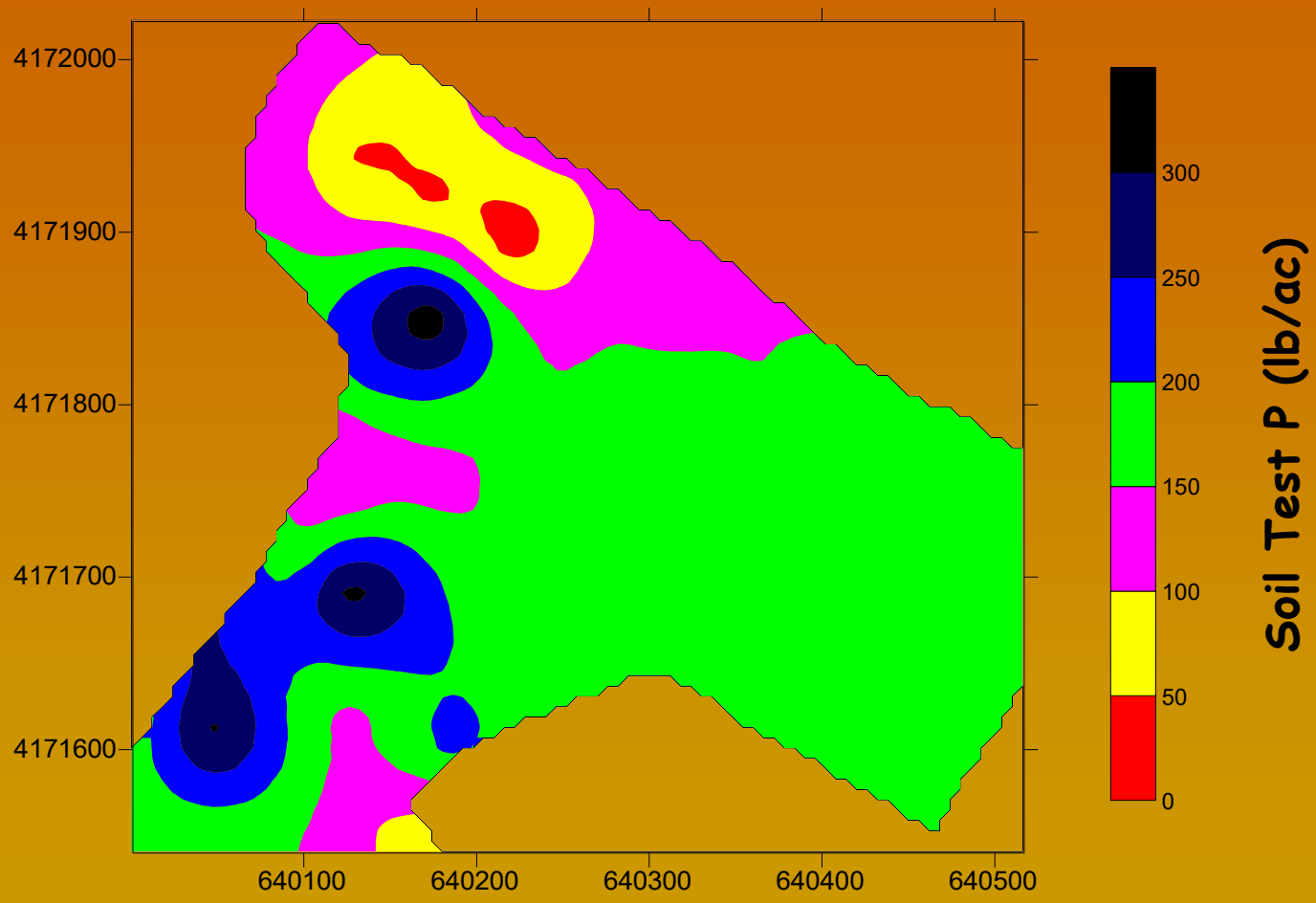


D'Angelo, pers. comm.

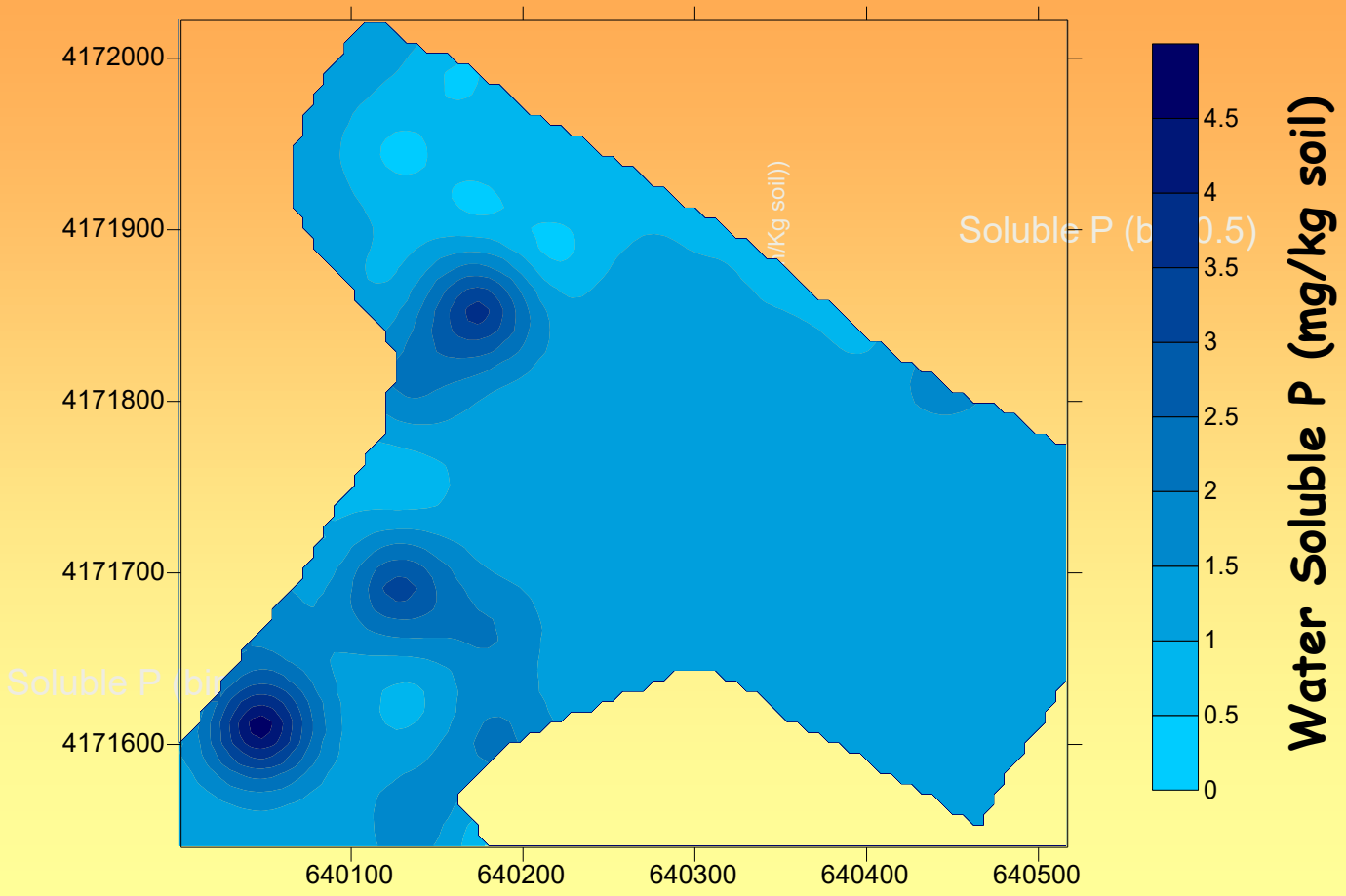
Predicting Water Soluble P from Mehlich III P on 175 Samples Taken from 3 NT Fields



Mehlich III Soil Test P – Field 912



Water Soluble P – Field 912



Environmental Consequences

Nutrient management is being driven to be more timely and more precise in meeting crop nutrition needs.

Single large dose not very likely for N (manure, biosolids) or P (any source) because of these externalities.

Greater emphasis on a good soil testing program?

Summary

Stratification can be both good and bad, depending upon exactly what is stratified.

Biological, chemical and physical properties are stratified in the soil – that is why we call surface soil "topsoil".

Most stratification is both natural and good for plants. Some is not good.

Need to keep stratification – both good and bad – in mind, and monitor as appropriate.

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