Using No-till and Cover Crops to Reduce Phosphorus Runoff

How to Avoid SRP in Surface Water

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THE OHIO STATE UNIVERSITY EXTENSION

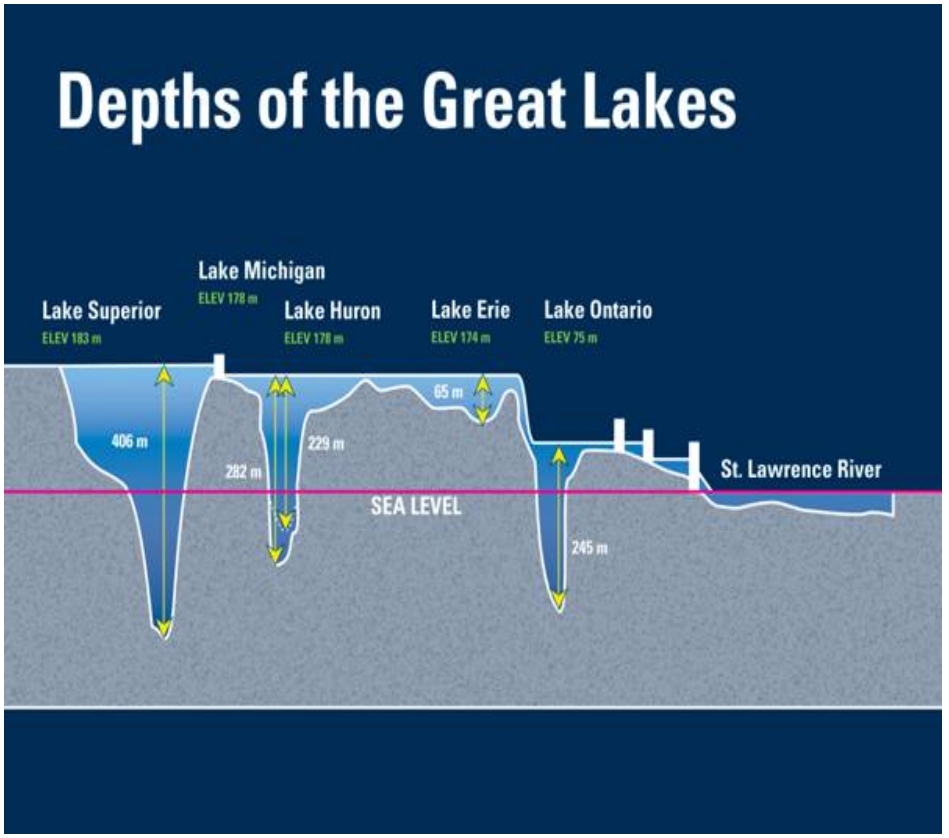
Agriculture in Lake Erie Basin

- 4.2 Million Acres Maumee Watershed
- 4.9 Million Acres in Lake Erie Basin
- 59.1% cropland
- 72% cropland in Northwest Ohio.

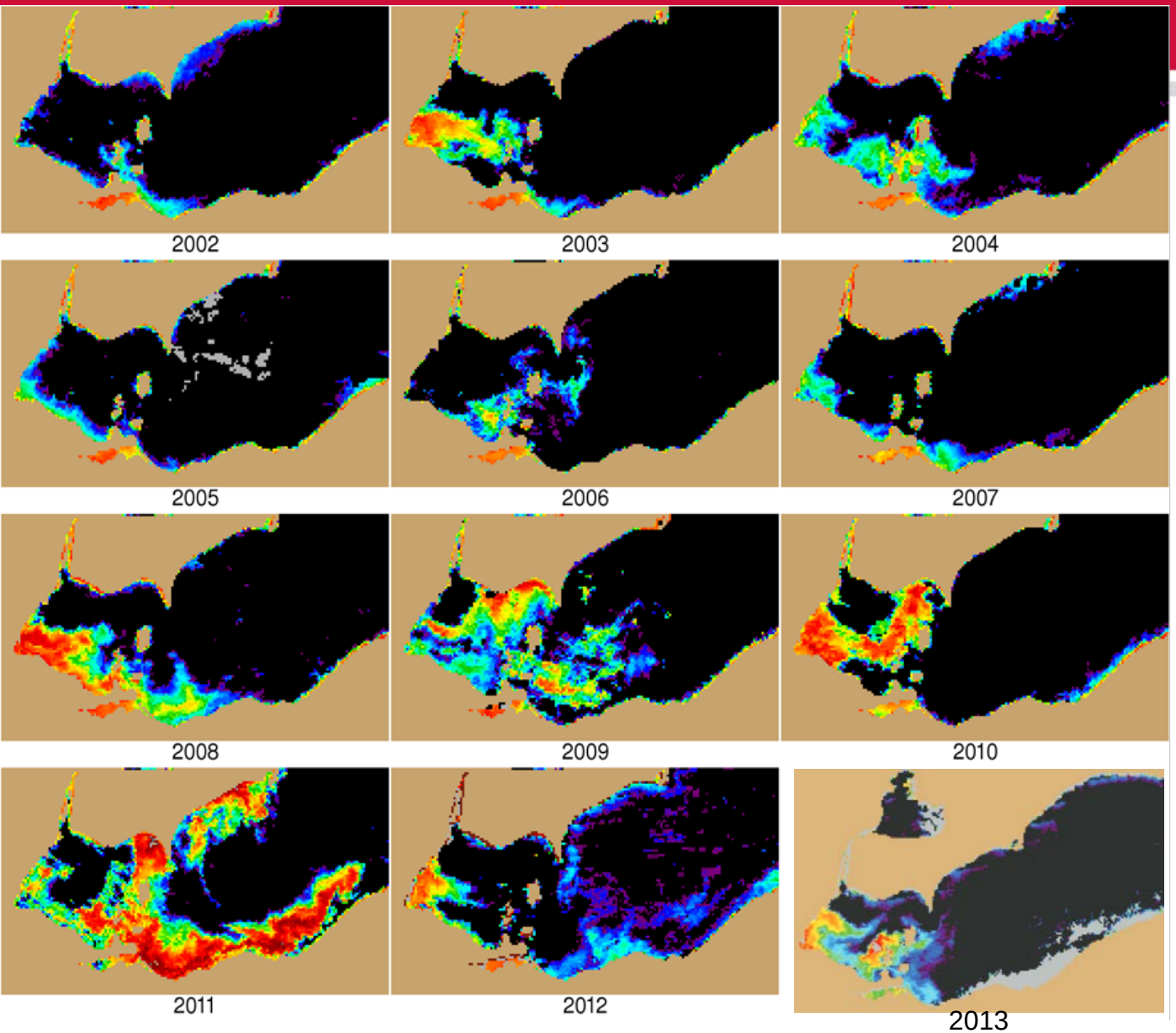
THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

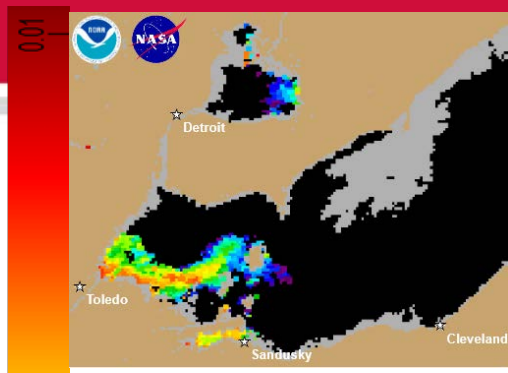
Interesting Lake Erie Facts

- 50/2 Rule
  - Superior 50% of water/2% of fish
  - Erie 50% of fish/2% of water
- $10.7 billion economic activity while employing 119,100 Ohio residents and generating $750 million in tax dollars



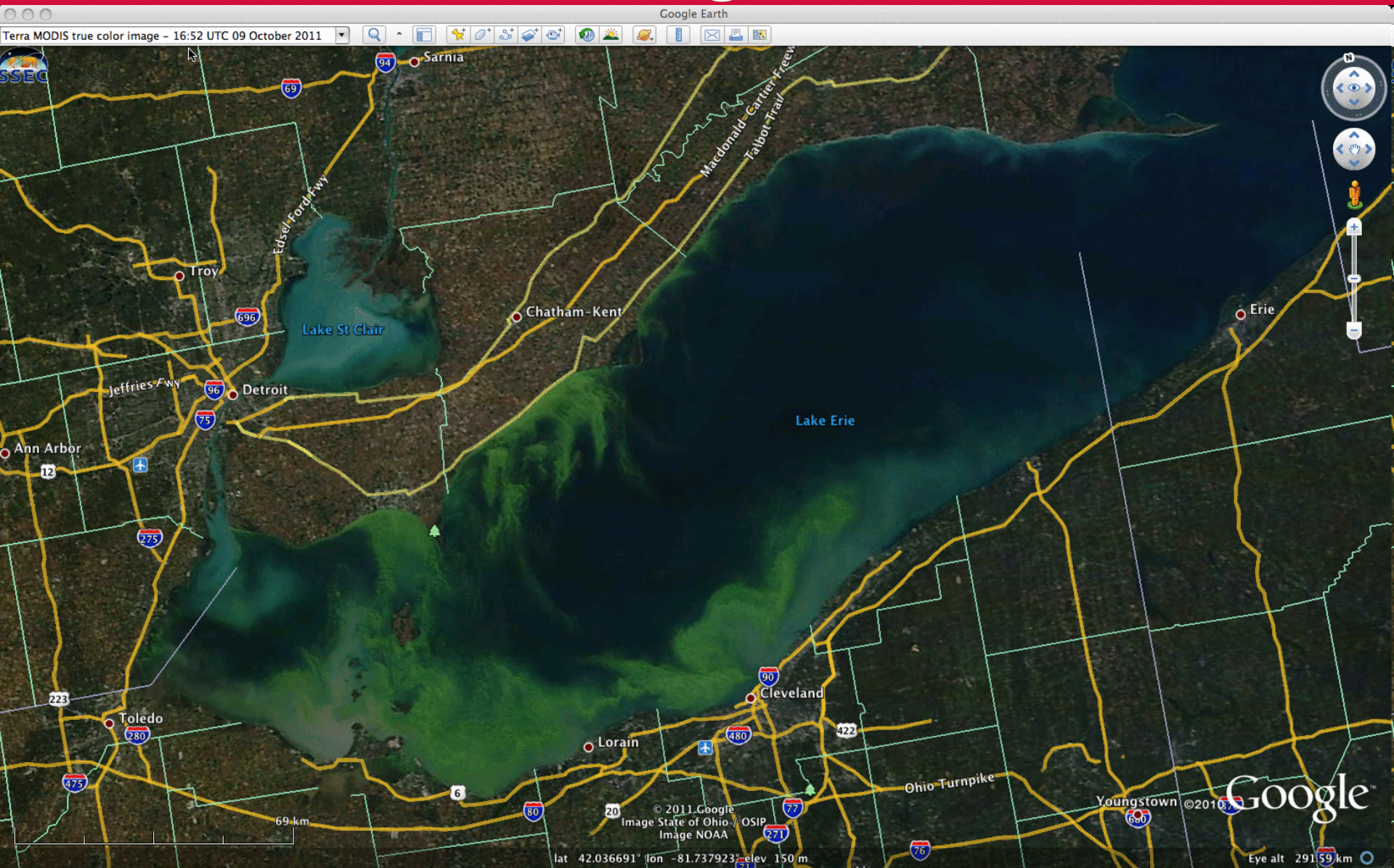
HAB Timeline





2014

10/09/11 Image Lake Erie



Grand Lake St. Marys 2010

SRP in Surface Water

Two Key factors:

a) Soil P concentration

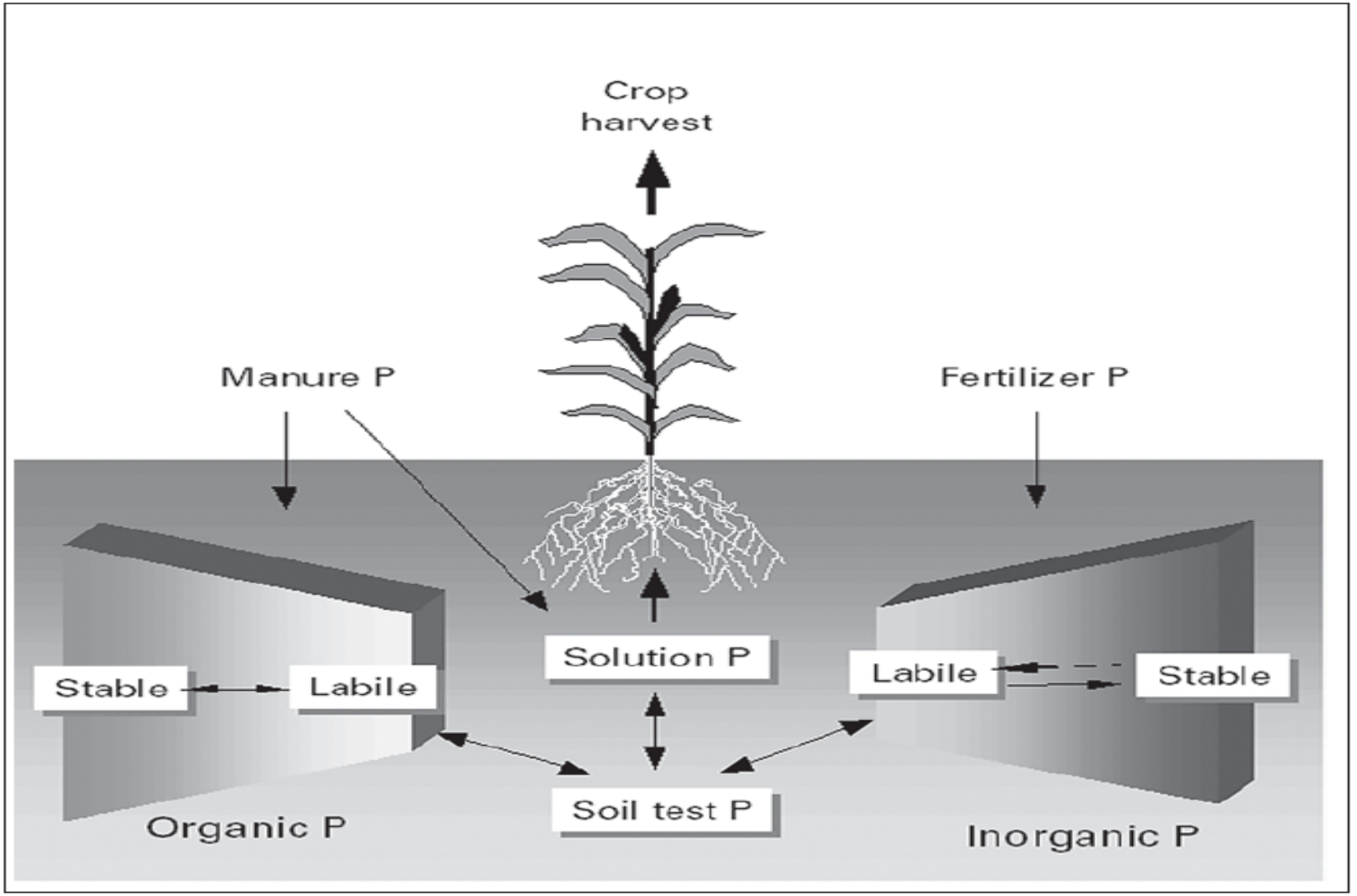
b) Transport Factor

Soil P concentration

* Transport Factor

= Pounds of P Lost to Surface Water

Phosphorus in Crop Production

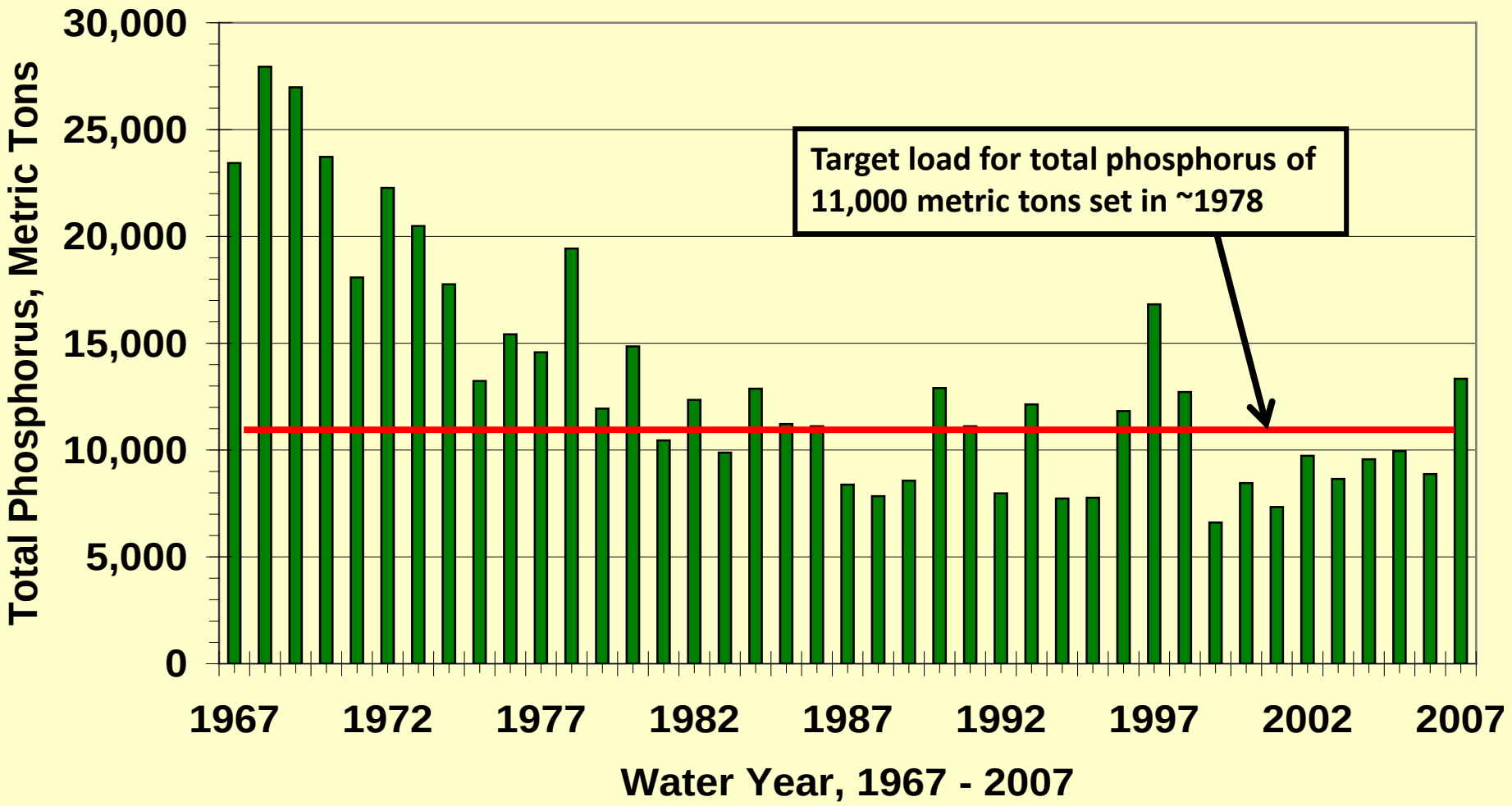


Common P Information

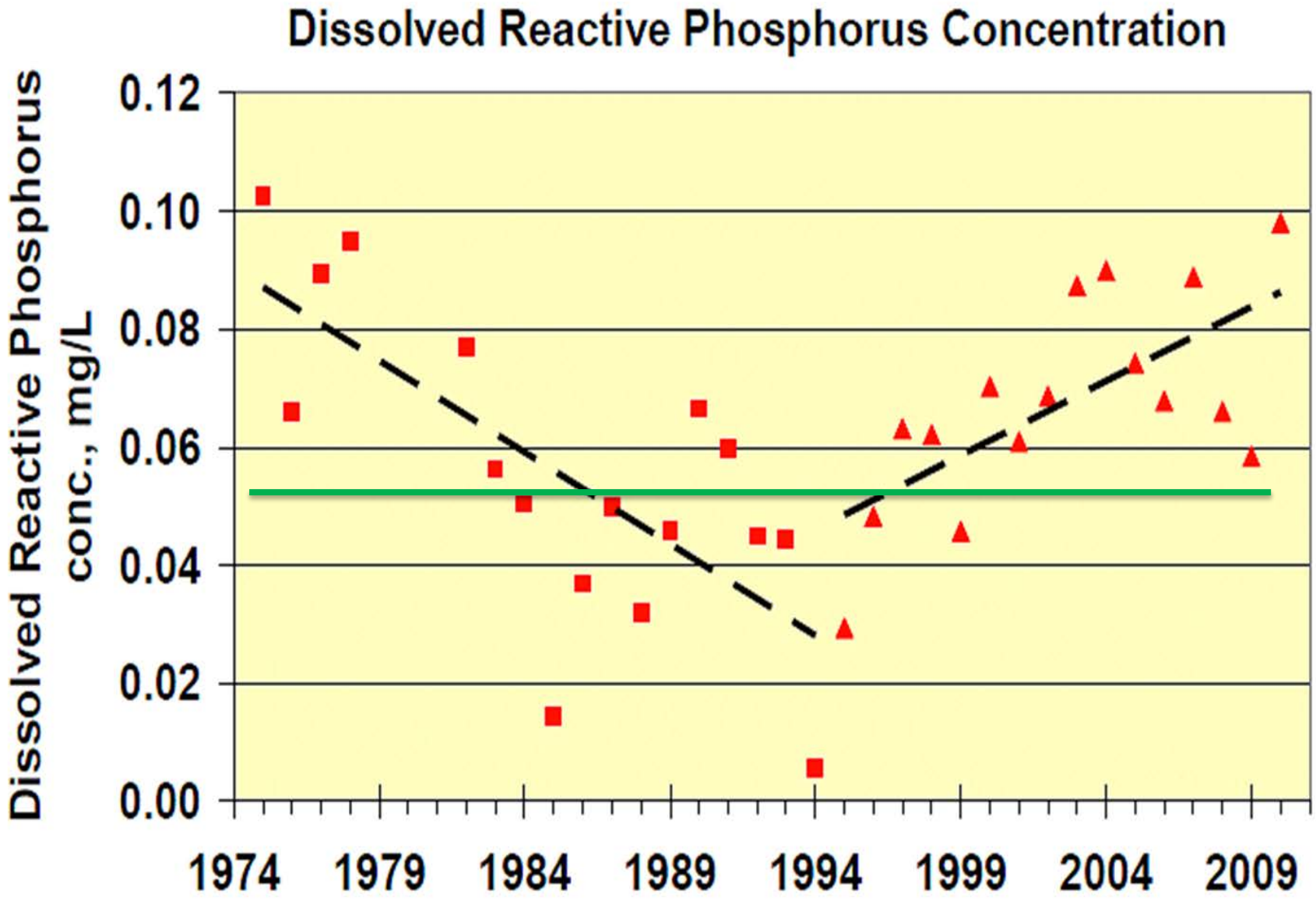
- Current P Use Efficiency 10% - 25% -50%

  Best estimate: 25% P Use Efficiency
- 80% of P runoff comes from 20% of land
- 60-90% of P runoff occurs in the 1-2 most intense rainfall events that occur each year!
- While P soil concentration is critical, most P runoff comes from fields close to streams.

Annual Loads of Total Phosphorus to Lake Erie, 1967-2007



Source: Hiedelberg University


Dissolved Reactive Phosphorus Concentration
Dissolved Reactive Phosphorus conc., mg/L
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1974
1979
1984
1989
1994
1999
2004
2009

Renewed Concerns about Lake Erie and Nutrient Loading

- Issue in 1960-1970's was Total P Loading
- Issue in 1990-2000's is Bioavailable or Dissolved Reactive Phosphorous

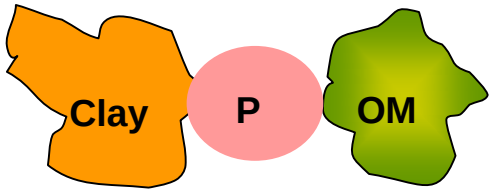
- Key facts about P: 60-90% of P runoff occurs in 1-2 rainfall events each year.
- 80% of the P is coming from roughly 20% of the land.

Organic Phosphorus

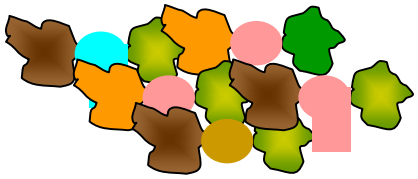
About 50-80% of the Available P in soil is organic.

P stabilizes the OM and forms a bridge to the clay.

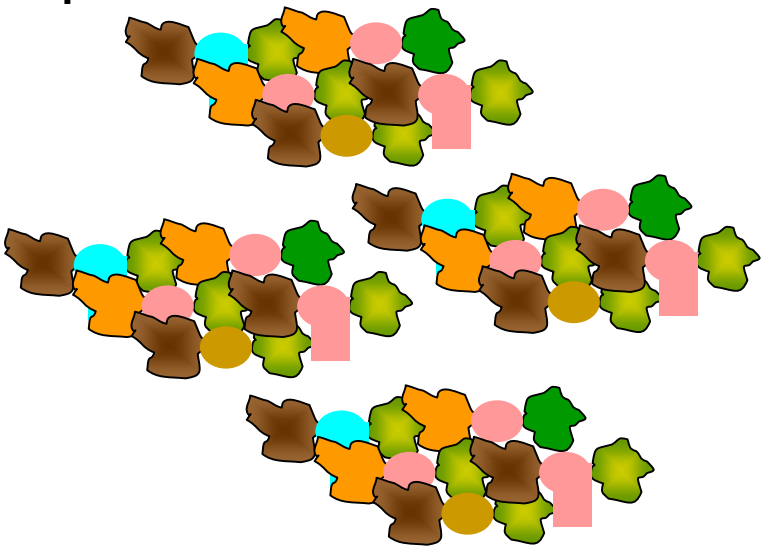
Our current P use efficiency is 25-30%. Microbes unlock P chemical bonds and make P plant available.



Clay-P-OM



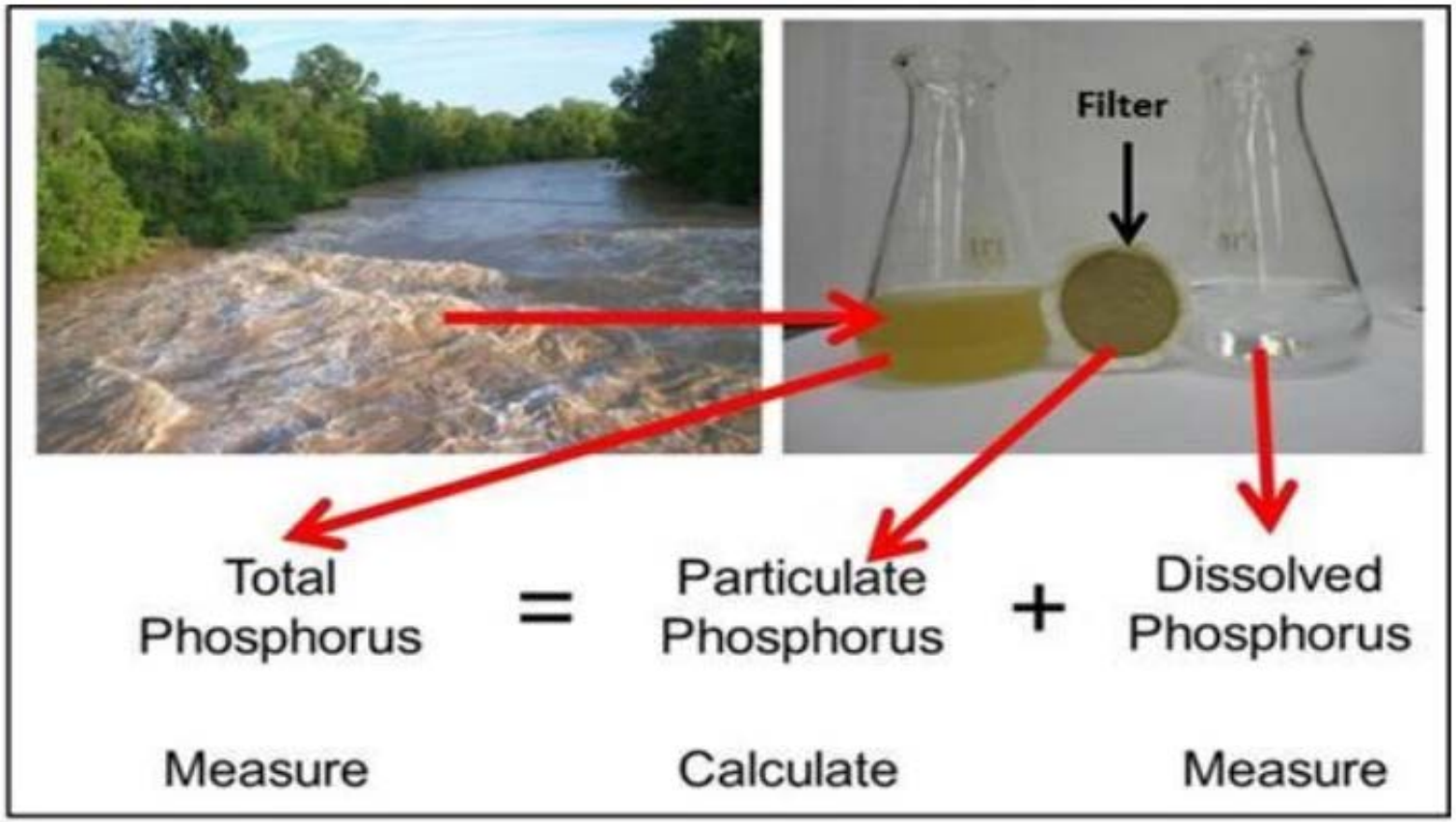
$(Clay\text{-}P\text{-}OM)_x$



$((Clay\text{-}P\text{-}OM)_x)_y$

Islam, 2010

Phosphorus Testing



Phosphorus Form and Availability to Algae

	Phosphorus form	% Bio Availability	Results
	Particulate	30	Algae grow slower
	Soluble	100	More available and quicker growth

Phosphorus Speciation

- Plant Available P
- Soluble Reactive (SRP) P_i Inorganic P - P_i
- Exchangeable (ExP) P_o Active Carbon- P_o

- Slowly or Not Plant Available P
- Ca^{2+} /Mg^{2+} Calcium/Magnesium- P_i
- Fe^{3+} /Al^{3+} Iron/Aluminum- P_i
- Res P_o Humus - Residual P_o
- Total P = All P_o + All P_i

Ferric–P to Ferrous-P

$2\ Fe^{3+}\text{-}3H_2PO_4$ $\rightarrow$ $H_2PO_4 + 2\ Fe^{2+}\text{-}2H_2PO_4$

- Fe^{3+} $\rightarrow$ P + Fe^{2+}

Caused by Saturated Soil Conditions and Lack of Oxygen in soil profile.

Iron is releasing SRP when soils become flooded with water.

Let's look at some common practices that have a negative impact on soil health and water quality

Long Term No-Till vs. Rotational Tillage

Both Fields are a Corn/Soybean Rotation

These pictures are of a newly emerging corn crop

NoTill soybeans then StripTill Corn

NoTill Soybeans then Tilled corn

Saturated Soils

- Under saturated soil conditions, soil microbes strip or release oxygen.
- Example NO^{3-} becomes N_20 and N_2 with bacteria striping the oxygen away from the nitrate causing denitrification.
- What other oxides exist in the Soil?

Phosphorus Speciation

Oxidization (Lose Electrons)	Reduction (Gain Electrons)
Iron (III) - Fe^{3+} (Ferric Fe) Yellow-Red	Iron (II) - Fe^{2+} (Ferrous Fe) Yellow-Grey-Blue
Manganese – MN^{2+}	Manganese – MNO_4^-
Copper – Cu^{2+}	Copper – Cu^{+}

OSU Research study

- Sundermeier, Islam, Hoorman 2013-2014
- Took 50 soil samples comparing no-till versus conventional, cover crop versus bare soil, organic versus conventional, manure (poultry, dairy, none), and crop rotation on Hoytville clay soil.
- Samples taken at following depths:

10 cm (4 inches), 20 cm (8 inches),

30 cm (12 inches)

Key Findings

- Management influences P soil distribution.
- Most soil P tied up by Residual P_o, Fe/Al, and Ca/Mg.
- Only a small amount is SRP or P_i (<0.5%)
- Concentration of P decreases with increasing soil depth.
- SRP and EP (which are plant available) are influenced by management practices and soil depth.

Stratification of P by Crop Rotation

Crop Rotation	SRP	EP	CaP	FeP	Res P	Total P
c-s-w	0.2c	2.6c	5.1b	6.8c	2.0a	2.3b
c-c	0.3c	3.4c	**11.5a**	19.4b	**1.6b**	2.1b
c-s	0.3c	0.6d	**13.0a**	**28.1a**	**1.5b**	2.8b
s-s	0.3c	0.3d	5.7b	**24.7a**	2.1a	**2.6a**
Alfalfa	0.9b	5.7b	6.6b	1.4d	2.0a	2.1b
Field Grass Waterway	**1.7c**	**7.0a**	3.0c	18.3b	1.8a	**2.5a**
Forest	**1.5c**	**7.3a**	1.6c	1.4d	1.9a	1.8c

Vegetated fields had higher SRP &EP? What happened to the SRP in tilled fields?

Cover Crops versus Control

SRP	EP	CaP	FeP	Res P	Total P
Cover Crops					
0.34b	**1.23a**	21.2a	25.7a	**147.7b**	**196.1b**
	8.8X				
Control					
1.42a	**0.14b**	18.0b	27.1b	**162.8a**	**209.5a**
4.2X				**1.1X**	**1.07**

Cover crops had significantly lower soil concentration of P in the SRP (4.2x less), And Res P, but much higher EP (8.8X).

Cover Crops vs Control Stratification

SRP	EP	CaP	FeP	Res P	Total P
Cover Crops					
0.4b	**61.7a**	1.6a	1.4a	1.5b	**2.0a**
	9.1X				**1.25X**
Control					
1.8a	**6.8b**	1.4a	1.4a	1.6a	**1.6b**
4.5X					

Cover crops (Red clover) had significantly lower soil stratification of P in the SRP fraction but significantly higher EP and TP fractions.

Mercer County Study

- Grand Lake Watershed, Mercer County, Ohio
- Two contrasting soils: Epiagualfs (Blount) and Agriaquolls (Pewamo)
- Seven sites for each soil (low to extremely high Bray $P_{1,}$ grass, and forest).
- Soil samples:<25, 25-75, 75-150, 150-300, and >300 PPM Bray P_1.
- Depth (0-1, 1-3, 3-6, 6-9, and 9-12 inches).

Agriaquolls (Pewamo)

P Level Bray P_1	Fe/Al-P (mg/kg)	Res-P (mg/kg)	TP (mg/kg)	Ratio Res/Fe	SOM (%)
Low (<25 PPM)	108.0	570.5	711.2	**5.3**	2.9
Medium (25-75 PPM)	125.1	592.9	740.1	**4.7**	3.1
High (75-150 PPM)	286.6	736.3	1052.2	**2.6**	2.9
V. High (150-300 PPM)	275.0	473.9	774.4	**1.7**	1.6
Ex High (>300 PPM)	345.8	655.1	1052.0	**1.9**	3.3
Grass	47.3	449.1	532.5	**9.5**	8.6
Woods	36.2	261.1	321.9	**7.2**	12.9

Epiagualfs (Blount)

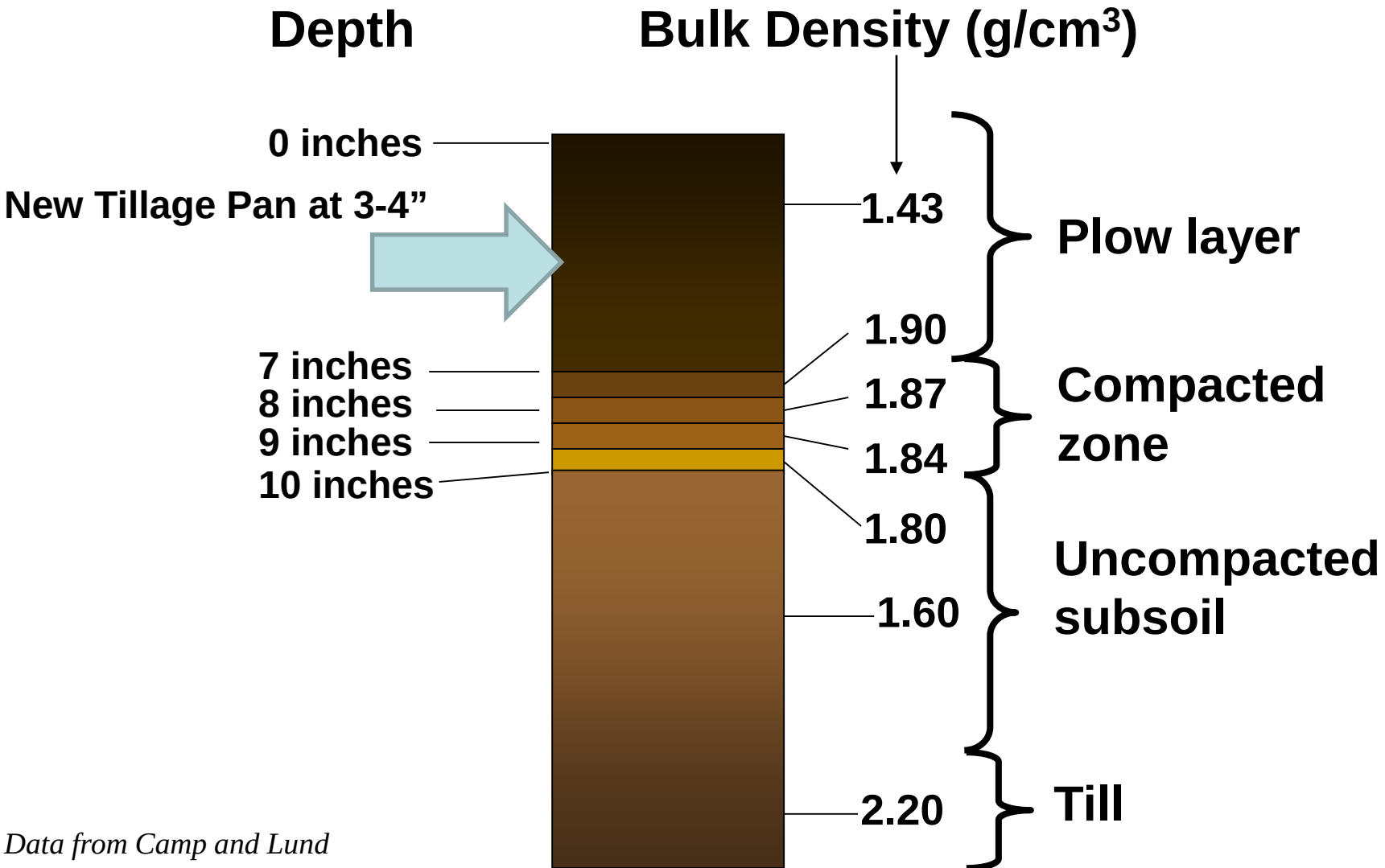
P Level Bray P_1	Fe/Al-P (mg/kg)	Res-P (mg/kg)	TP (mg/kg)	Ratio Res/Fe	SOM (%)
Low (<25 PPM)	104.3	333.3	455.2	**3.2**	3.2
Medium (25-75 PPM)	131.2	355.1	501.5	**2.7**	2.7
High (75-150 PPM)	178.9	550.8	753.4	**3.1**	3.1
V. High (150-300 PPM)	291.9	534.4	871.2	**1.8**	1.8
Ex High (>300 PPM)	280.3	557.2	668.3	**1.3**	1.3
Grass	50.9	436.3	515.4	**8.6**	5.2
Woods	37.7	477.8	551.6	**12.7**	5.1

Has Phosphorus Changed?

Not really. So What has changed since 1995?

1) **Weather: Increase number, higher intensity of rains, longer duration.**
2) **We have better environment for cyanobacteria. Warmer weather + more nutrients = Explosion**
3) **Change in farm size**
4) **More tile spaced closer together with more surface inlets.**
5) **Fertilizer applications have changed. More fall application to accommodate farm size.**
6) **More vertical tillage, larger farm equipment, more soil compaction.**
6) **Fertilizer Enhancers (Avail/Jumpstart)**
7) **Less Soil Organic Matter**

Bulk Density and Compaction

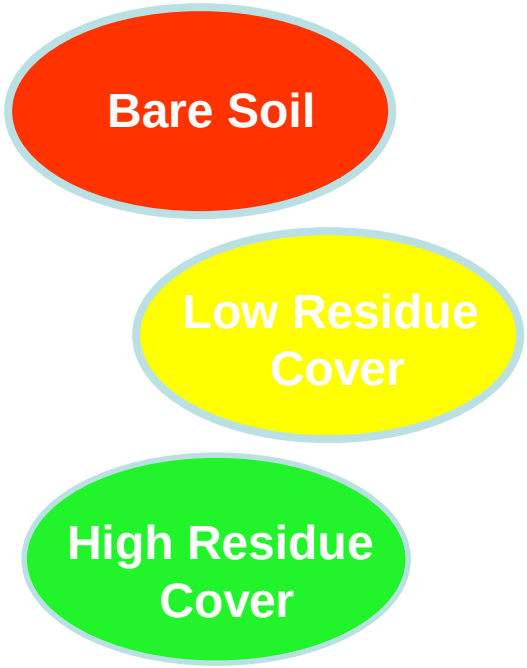


Data from Camp and Lund

Dynamic Properties: Infiltration

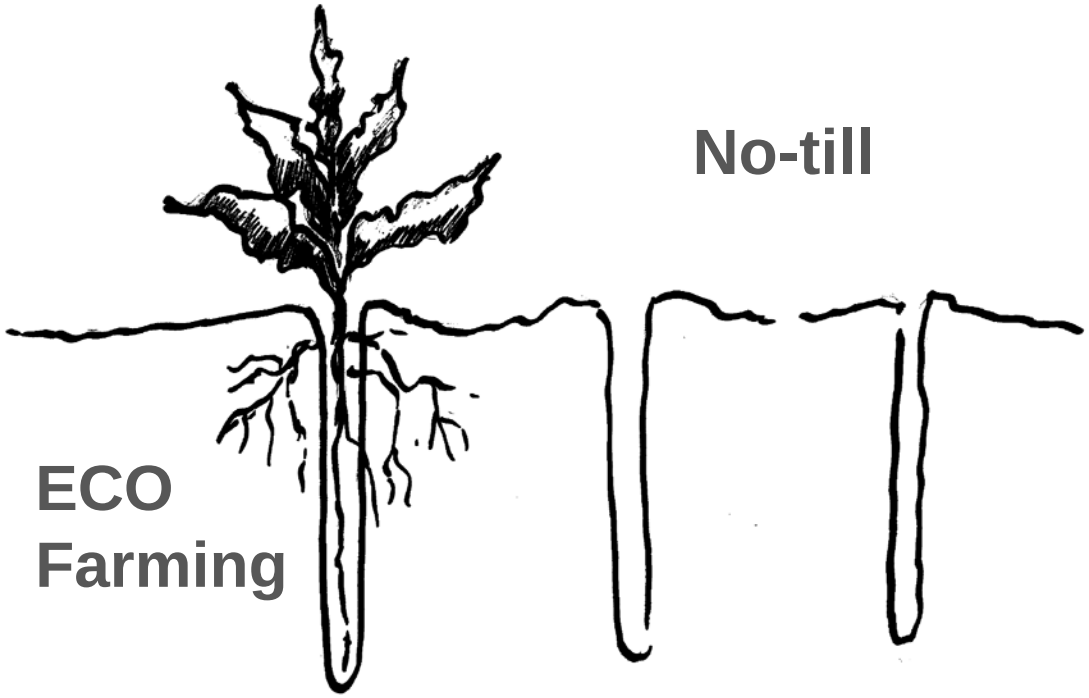
- If rainwater runs off field…. It is not available to the crop
  - Dynamic Soil Property greatly influenced by management

Tillage System	Water Infiltration Rate after 1 Hour (in/hour)
Plowed, disked, cultivated, bare surface	.26
No-tillage, bare surface	.11
No-tillage, 40% cover	.46
No-tillage, 80% cover	1.04



- Residue cover prevents soil crusts

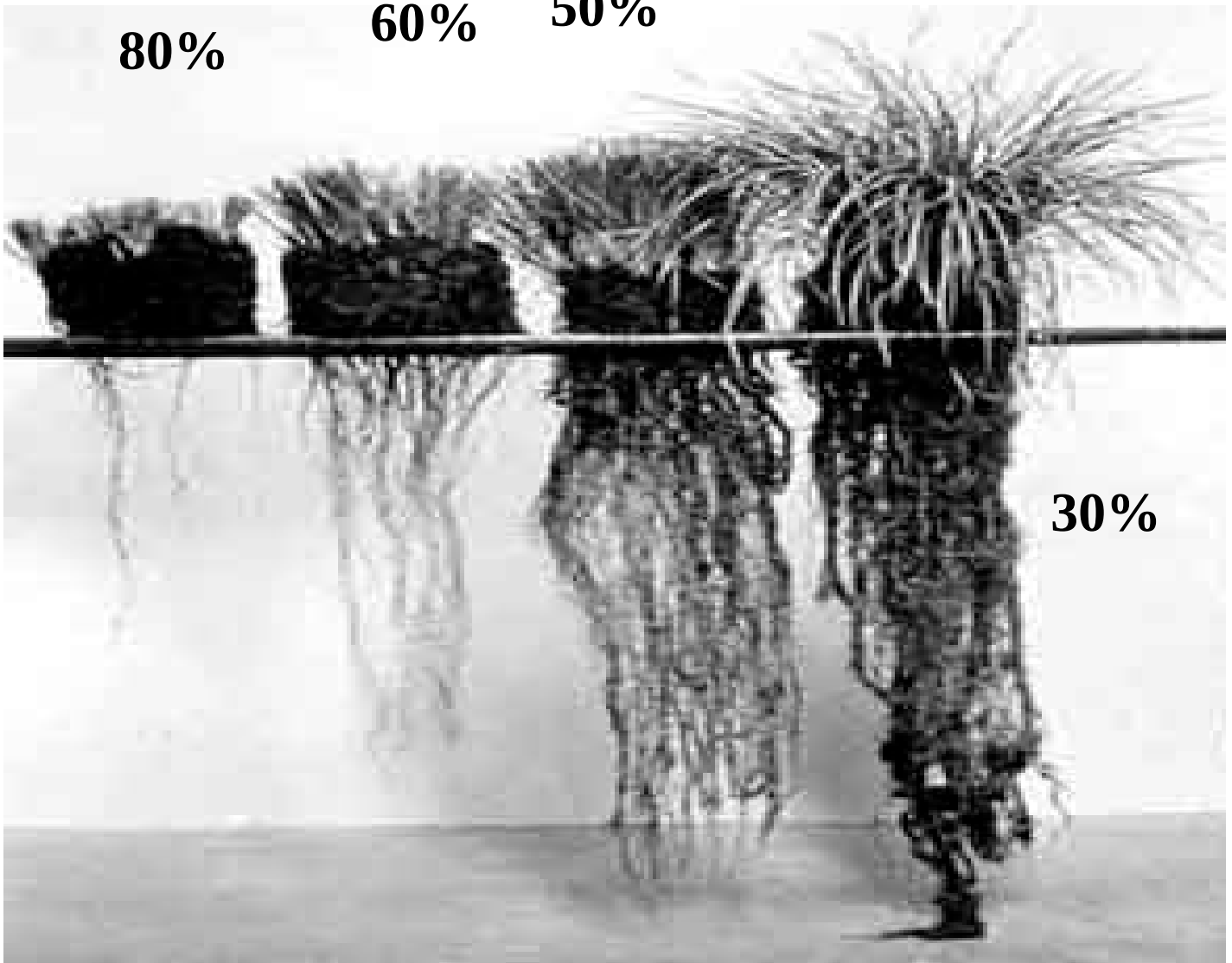
No-TILL creates macropores



ECO Farming & live roots acts like a biological valve to absorb N and P.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Managing plant roots affects nutrient recycling



Fertility Applications

- Frozen and snow covered applications have the greatest risk of off site movement whether manure or commercial fertilizer.

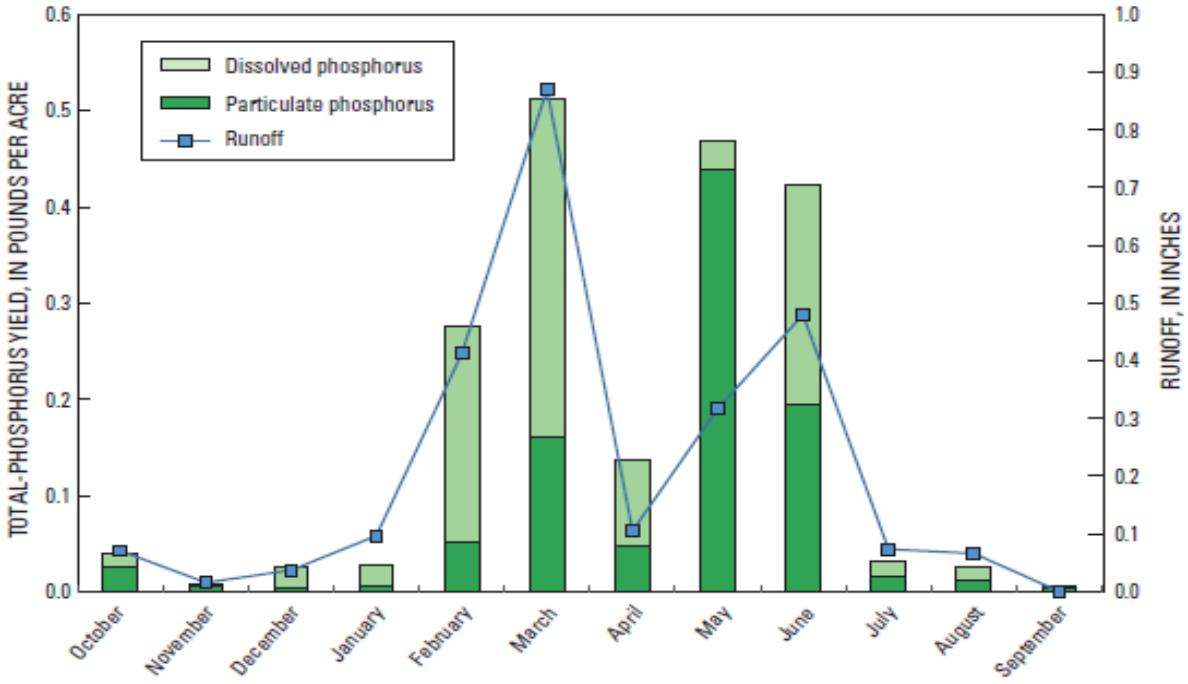


Figure 22. Mean monthly particulate- and dissolved-phosphorus yields and runoff, Discovery Farms and Pioneer Farm, water years 2003–8.

Benefits of Cover Crops

- Increase water infiltration – Move SRP_i down into soil profile.
- Decrease bulk density and increase pore space for both air and water – Less saturated soils.
- Increase soil organic matter content which improves soil structure and holds P tighter

  $SRP_i < EP_o$ and $FeP_i < Res\ P_o$