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How Soil Health can Improve Water Quality and Reduce Nutrient Runoff

Natural Resources Conservation Service

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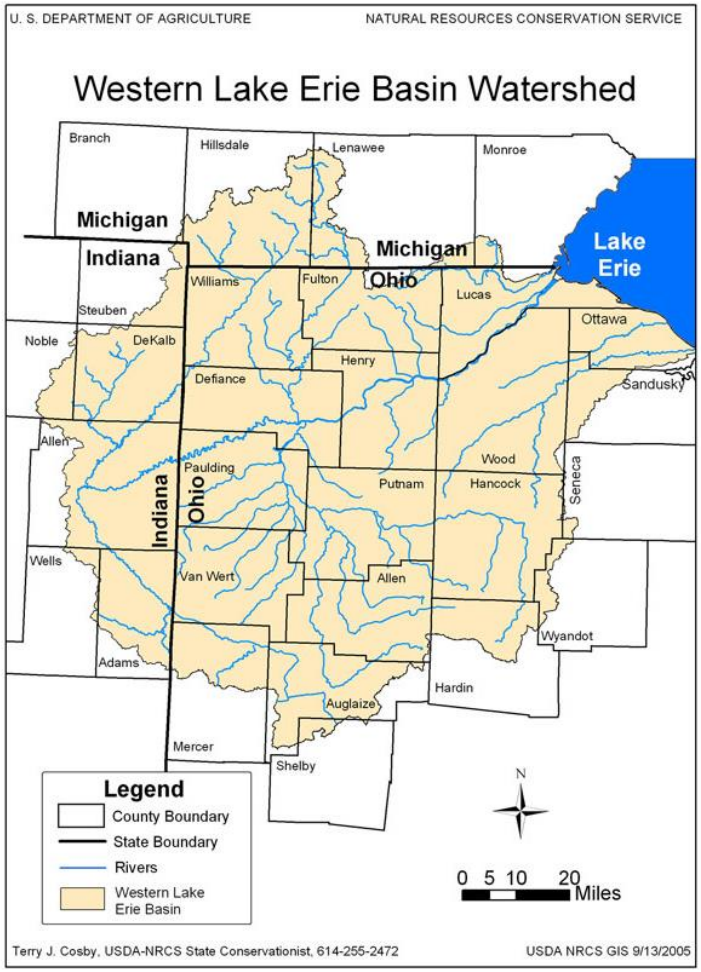
Agriculture in Lake Erie Basin

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



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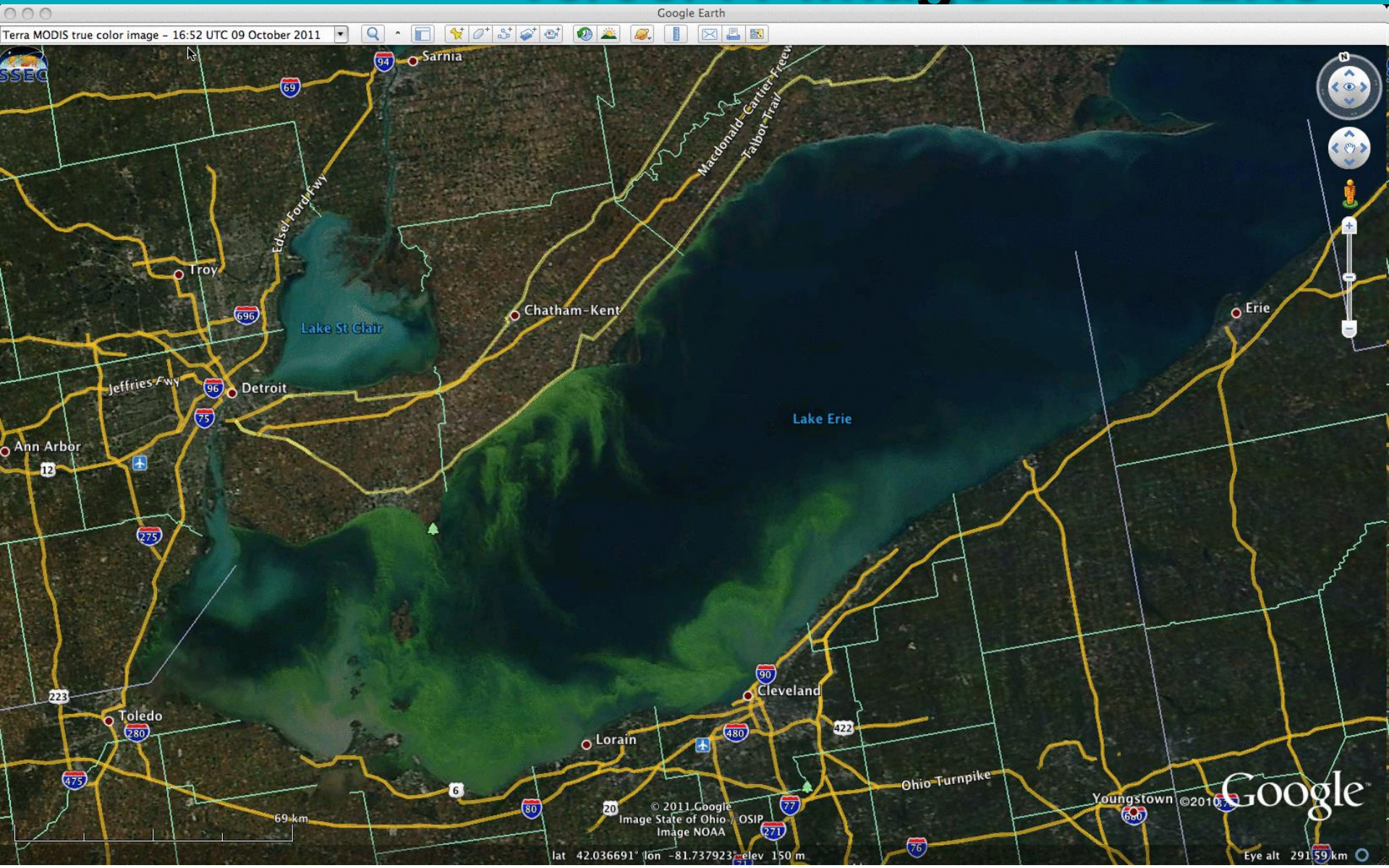
10/09/11 Image Lake Erie



Renewed Concerns about …

Lake Erie Nutrient Loading

- Issue in 1960-1970's was Total P Loading
- Issue in 1990-2000's is Bioavailable or Dissolved Reactive Phosphorous
- Current P Use Efficiency 10% - 50% OR **25%**
- 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.

SRP in Surface Water

Two Key factors:

a) Soil P concentration

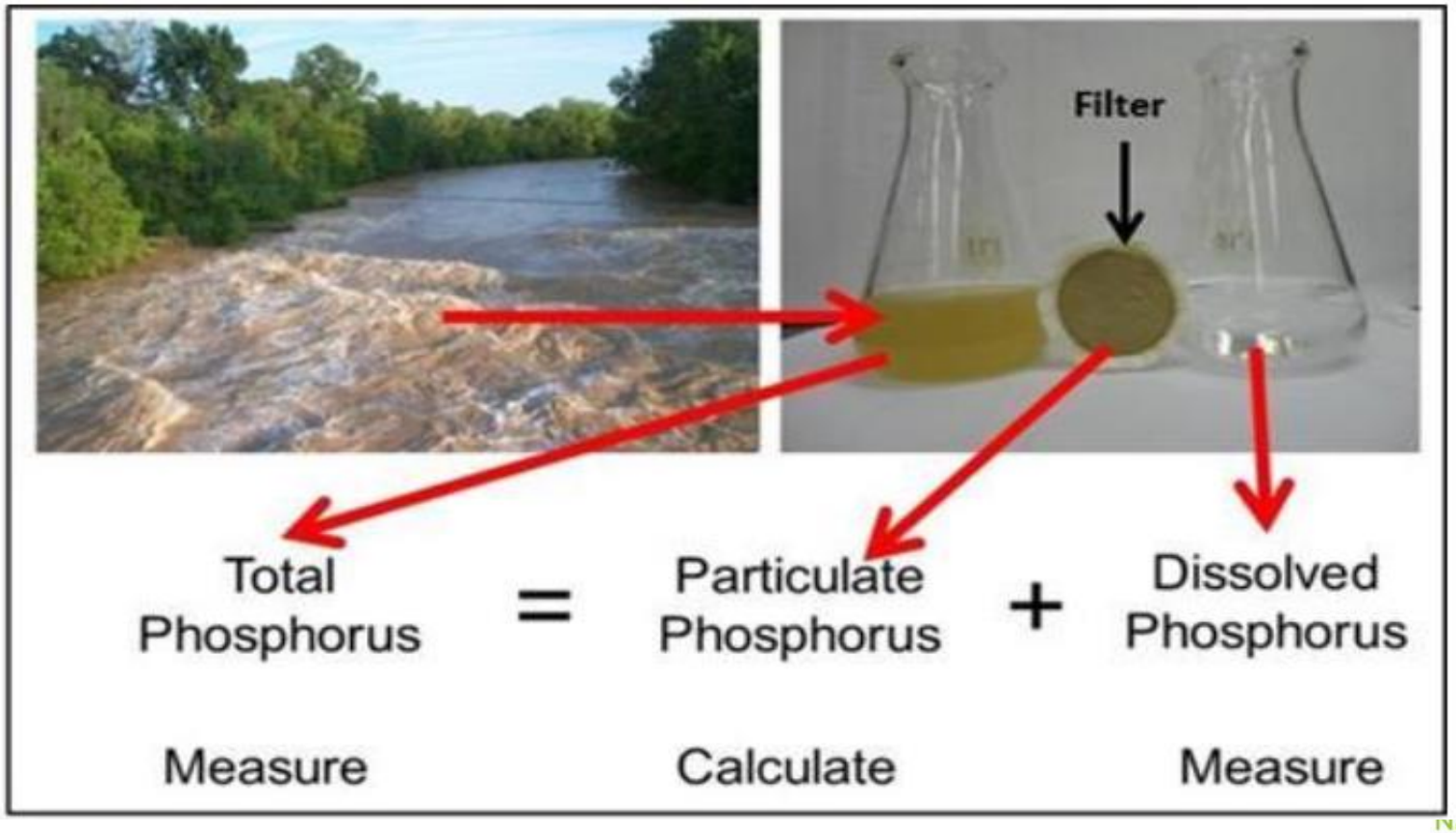
b) Transport Factor

Soil P concentration

* Transport Factor

= Pounds of P Lost to Surface Water

Phosphorus Testing

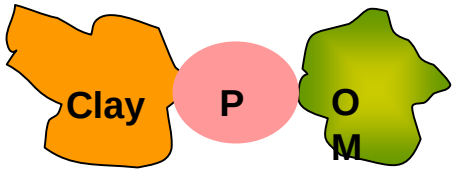


New Info: 70% of PP becomes SRP in water. Dr. Libby Dayton, Ohio State

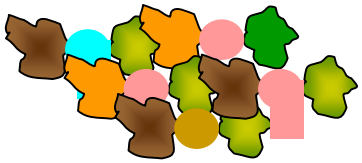
P Information

About 50-75% of the Available P in soil is organic. P stabilizes the OM and forms a bridge to the clay.

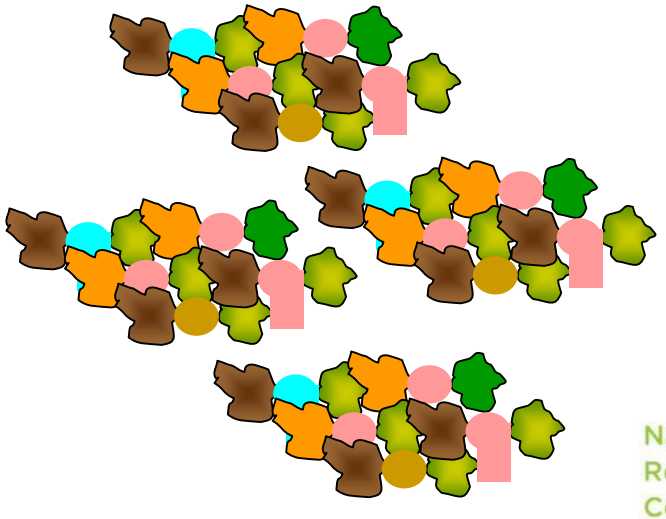
Our current P use efficiency is 10-50%. Microbes unlock P chemical bonds and make P plant available.



Clay-P-OM



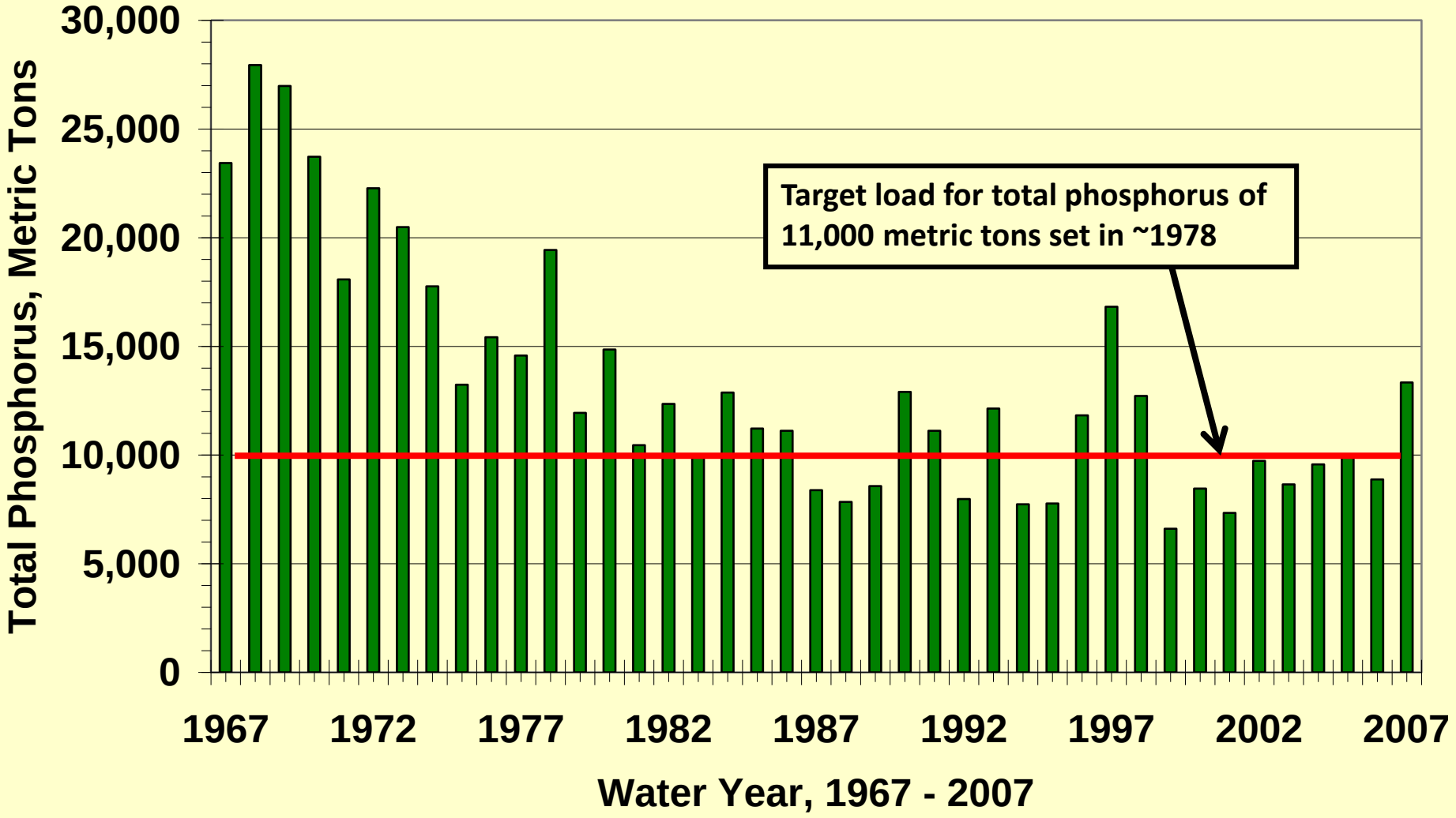
$(Clay\text{-}P\text{-}OM)_x$



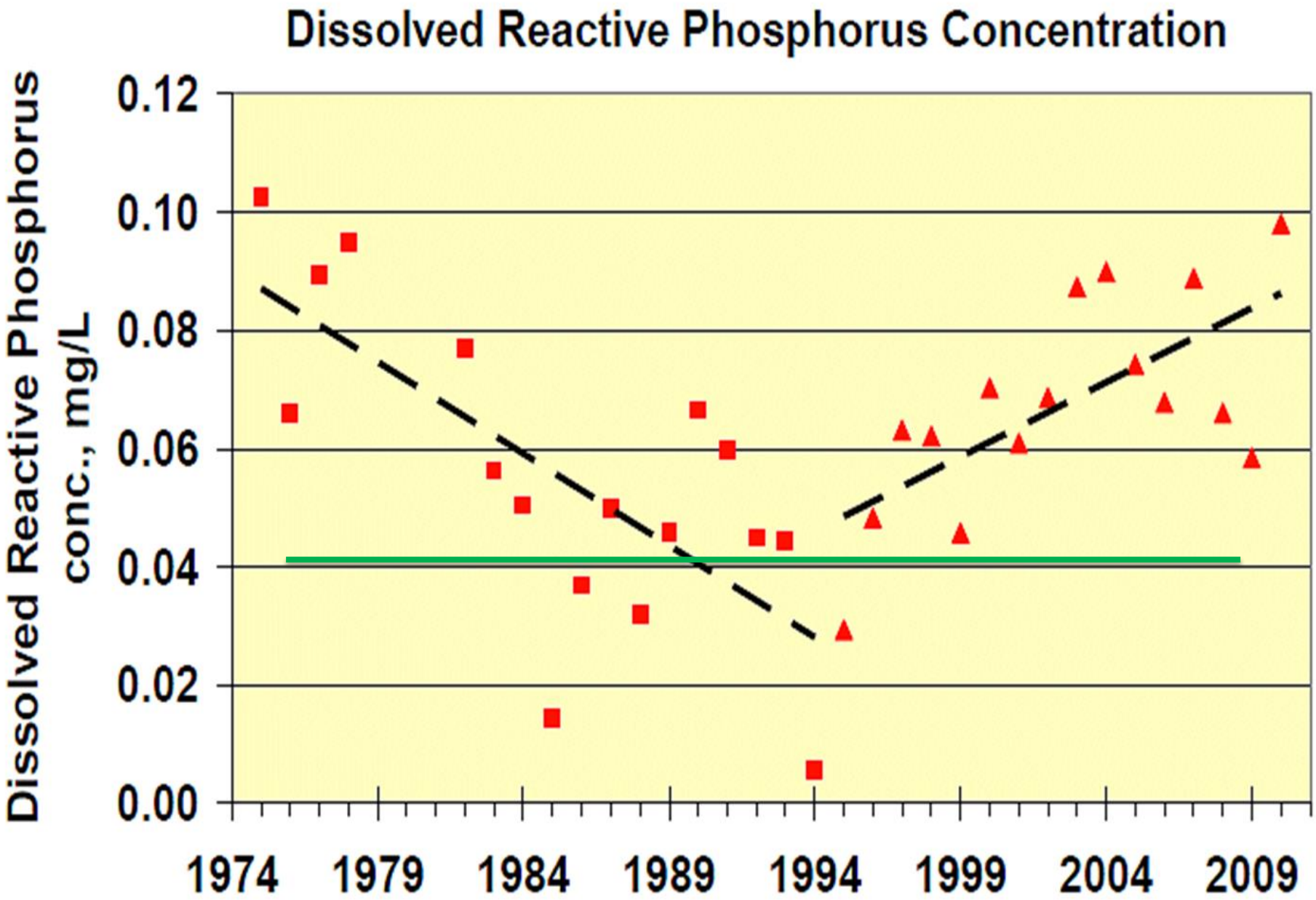
$((Clay\text{-}P\text{-}OM)_x)_y$

Islam, 2010

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



Source: Hiedelberg University



Source: Hiedelberg University

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

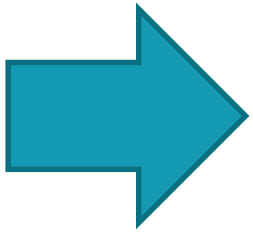
- Ca^{2+} /Mg^{2+} Calcium/Magnesium- P_i
- Fe^{3+} /Al^{3+} Iron/Aluminum- P_i

- Res P_o Humus - Residual P_o

- Total P = All P_o + All P_i

Ferric–P to Ferrous-P

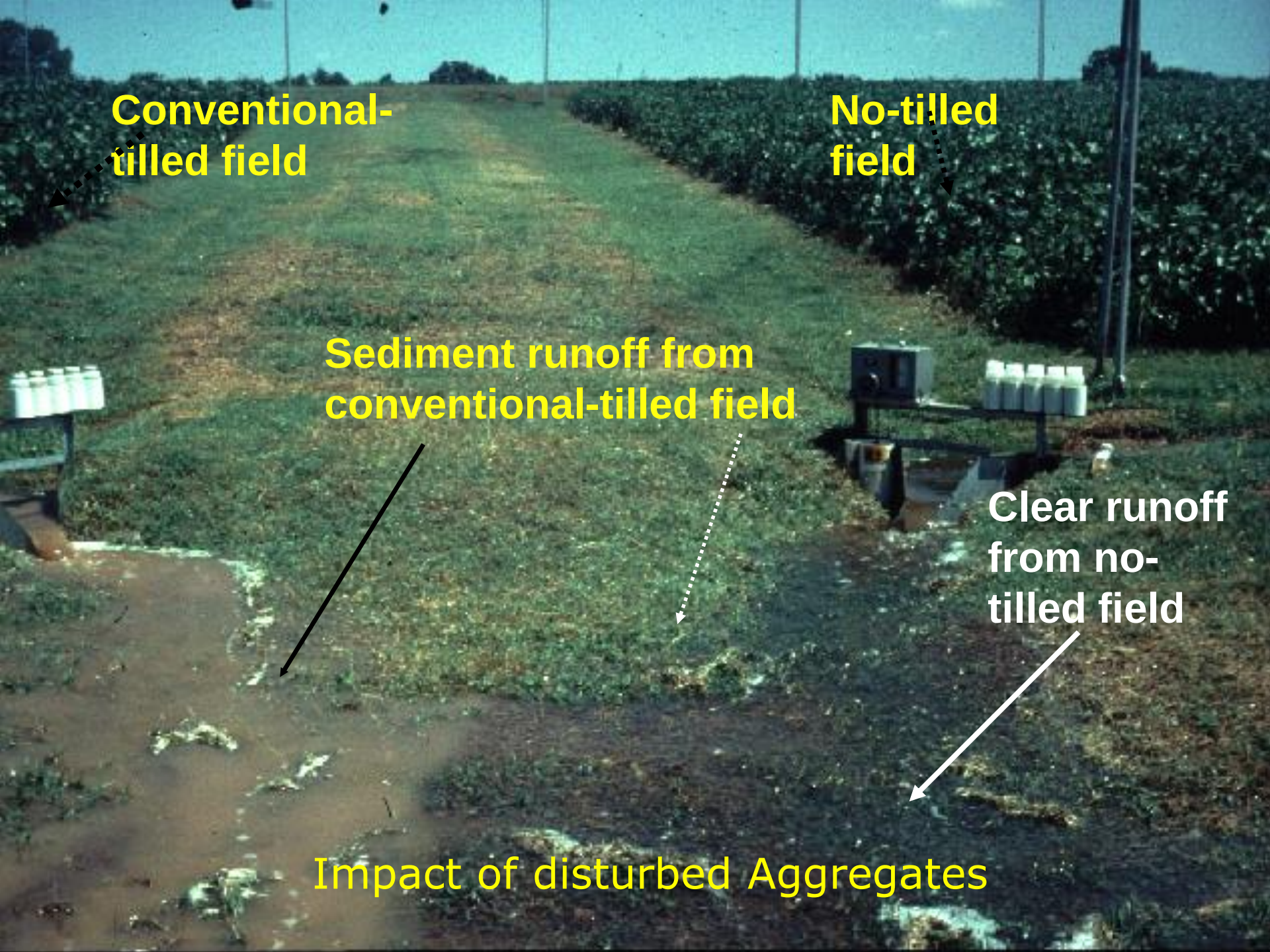
$2\ Fe^{3+}\text{-}3H_2PO_4$ $H_2PO_4 + 2\ Fe^{2+}\text{-}2H_2PO_4$



Fe^{3+} P + Fe^{2+}

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

Iron is releasing SRP and flows with the water when soils become saturated or flooded.


Conventional-tilled field
No-tilled field
Sediment runoff from conventional-tilled field
Clear runoff from no-tilled field
Impact of disturbed Aggregates

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

Source: Ohio Agronomy Guide: 12th Edition

- Residue cover prevents soil crusts

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Stratification of P by Crop Rotation

Crop Rotation	SRP	EP	CaP	Al/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**	**2.8**a
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	**1.7a**	**7.0a**	3.0c	18.3b	1.8a	**2.5a**
Forest	**1.5a**	**7.3a**	1.6c	1.4d	1.9a	1.8c

Vegetated fields had higher SRP & EP?

What happened to the SRP in agricultural fields?

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Cover Crops versus Control

SRP	EP	CaP	FeP	Res P	Total P
Cover Crops +NT					
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 + NT 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 + NT					
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.

P Forest VS Agriculture

Forested Watershed

- Soil Organic P = 645 Kg/Ha **50% Higher SOM**
- Inorganic P = 275 Kg/Ha
- **Runoff = 0.3 Kg/Ha**

Agricultural Watershed

- Soil Organic P = 314 Kg/Ha 50% Less SOM
- Inorganic P = 976 Kg/Ha **Mineralization 4x higher**
- **Runoff = 2.41 Kg/Ha** **Runoff was 8x higher**

Nature and Properties of Soil (Weil & Brady, 2017) page 650

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Agriaquolls (Pewamo)

P Level Bray P_1	Fe/Al-P (mg/kg)	Res-P (mg/kg)	TP (mg/kg)	Ratio Res/Fe Al	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

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Has Phosphorus Changed?

No! But Weather and Practices have…

1) Weather: Increase number, higher intensity, longer duration rain.

2) We have better environment for cyanobacteria. Warmer weather + more nutrients = Explosion HAB

3) Change in farm size with larger farms. Efficient hybrids

4) More tile spaced closer together with more surface inlets.

5) Fertilizer P chemistry has changed. C-S Rotations. More fall broadcast applications to accommodate farm size.

6) Tri-State Fertilizer Recommendations have safety factor.

7) Vertical tillage + larger farm equipment = soil compaction.

8) Fertilizer Enhancers (Avail/Jumpstart)

9) Less Soil Organic Matter

10) Less Acid Rain, change in P availability.

4.2pH to 5.2pH Rainwater → SRP

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Vertical Tillage

Has increased significantly since 1995 when SRP started Increasing!

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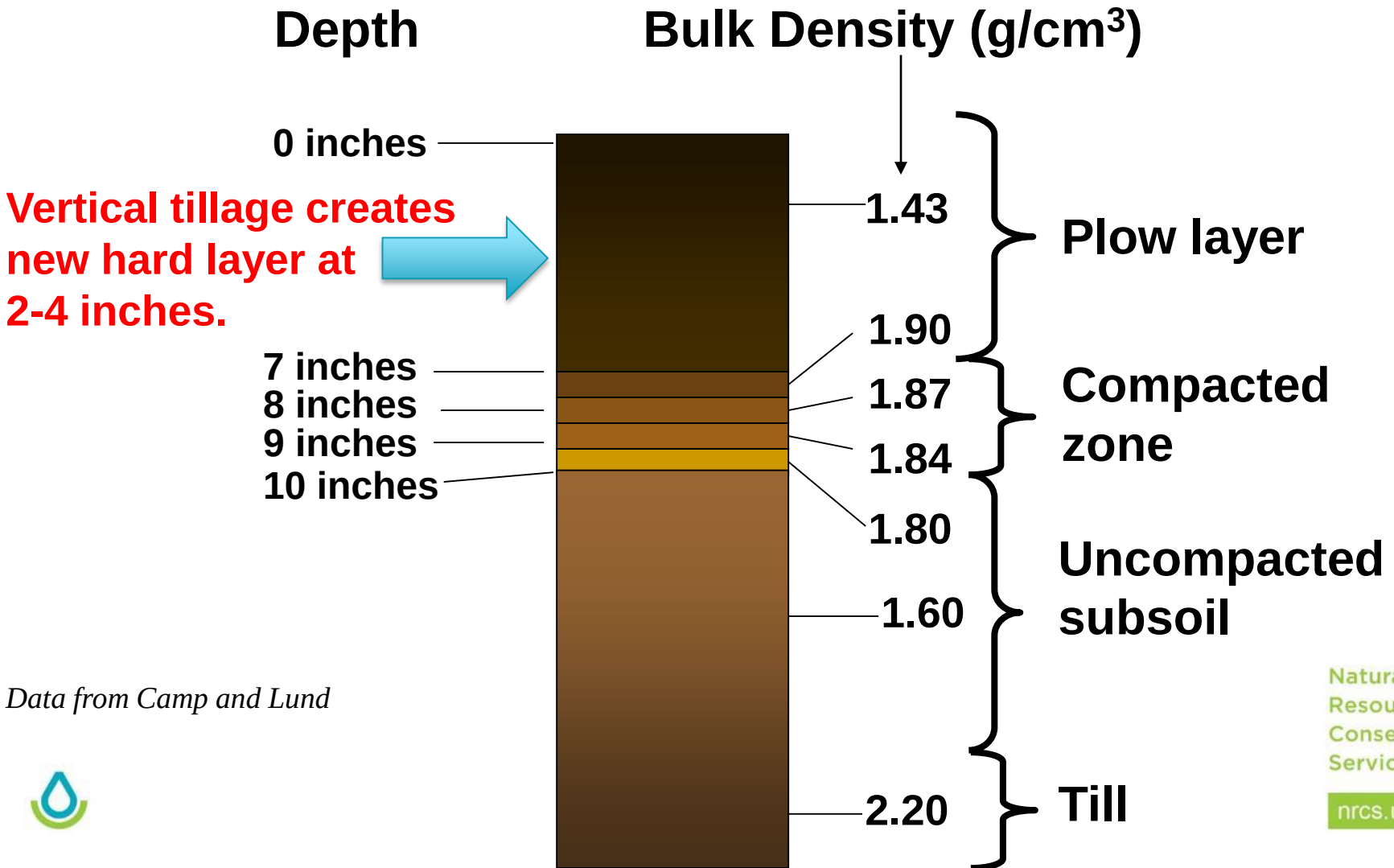
Bulk Density & Compaction



Data from Camp and Lund

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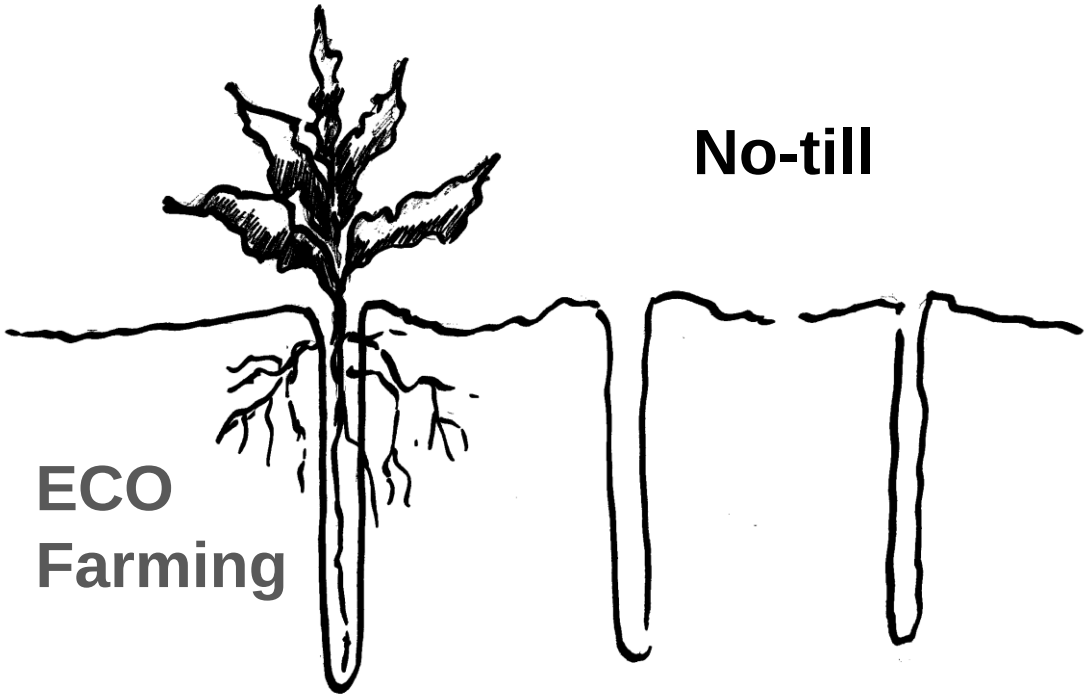
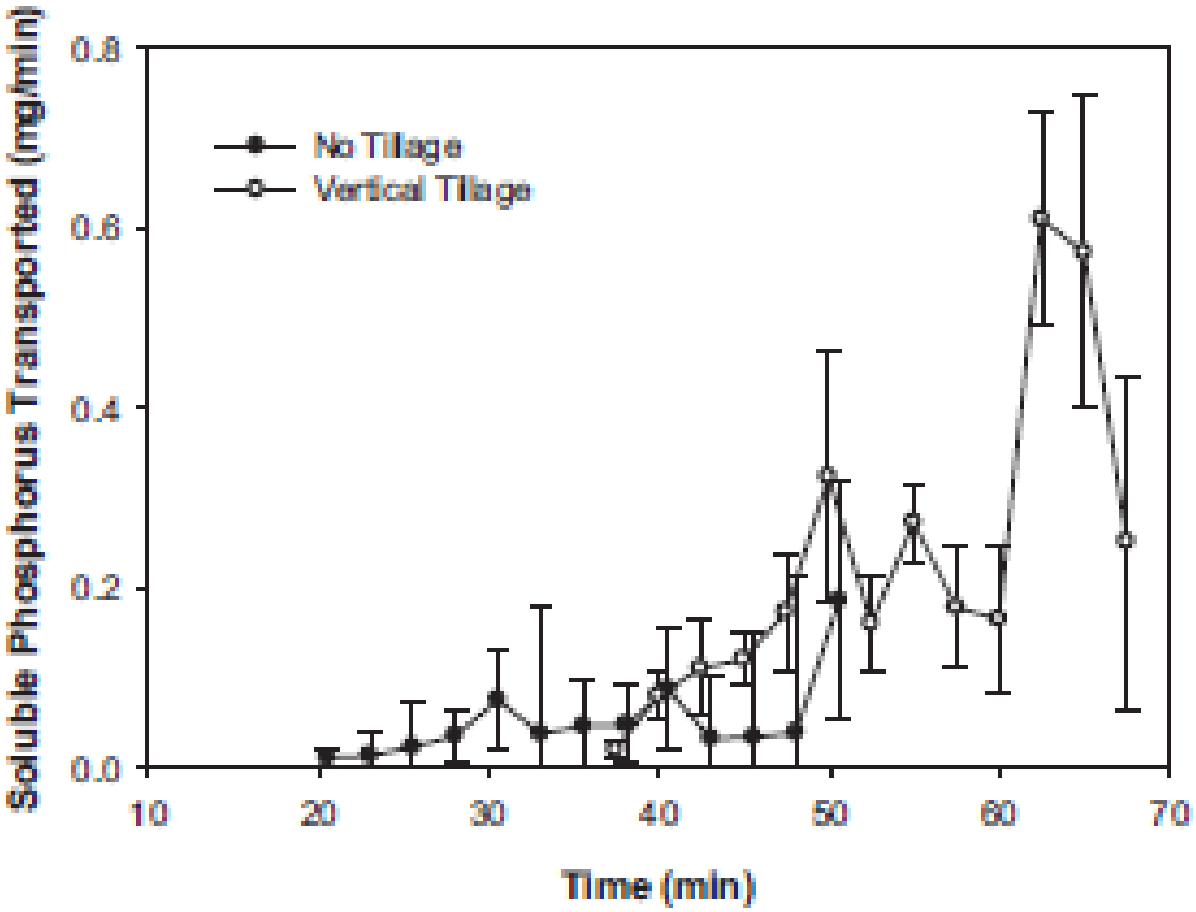
No-TILL creates Macropores



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

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

SRP Runoff



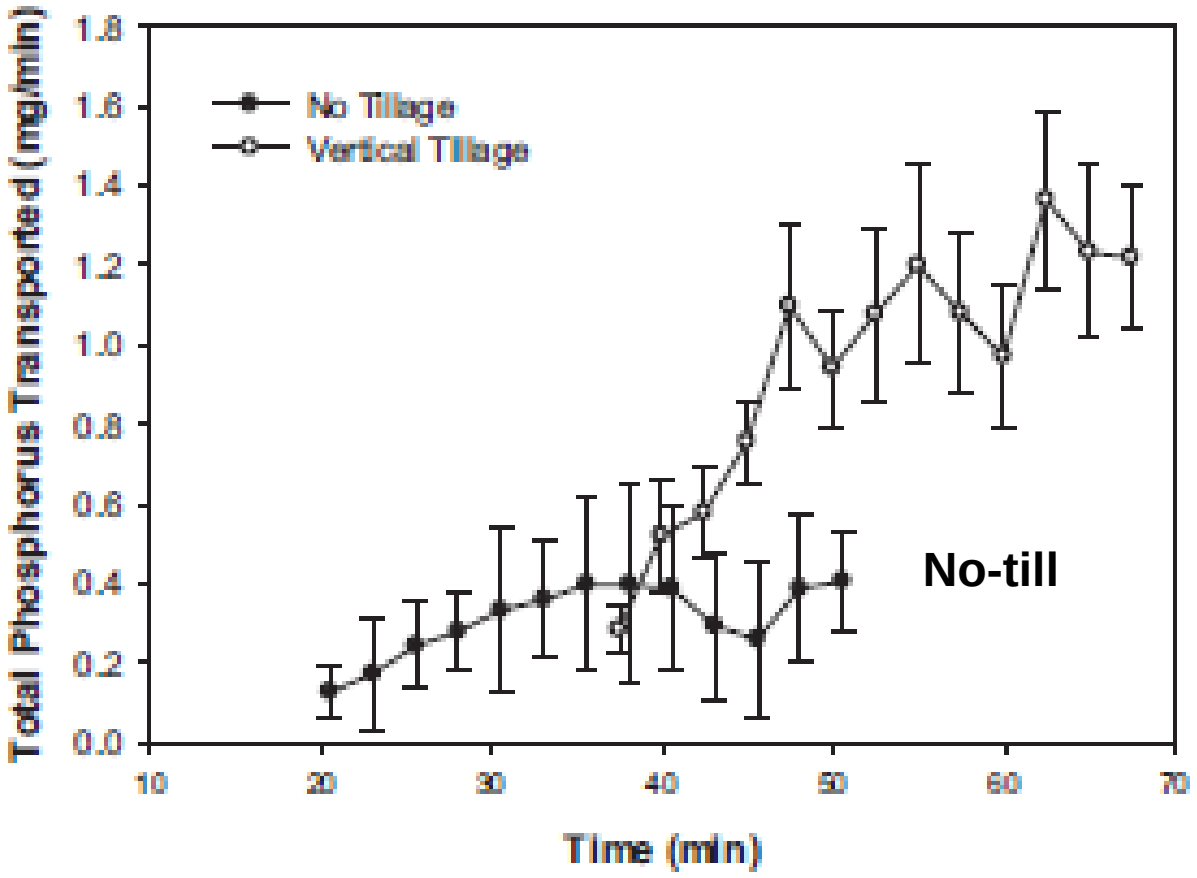
Vertical tillage

No-till

Fig. 1. Soluble phosphorus transported via runoff from no-tillage and vertical tillage plots. Error bars represent standard error.

Smith & Warnemuende-Pappas, 2015
Soil & Tillage Research 153:155-160

TP Runoff



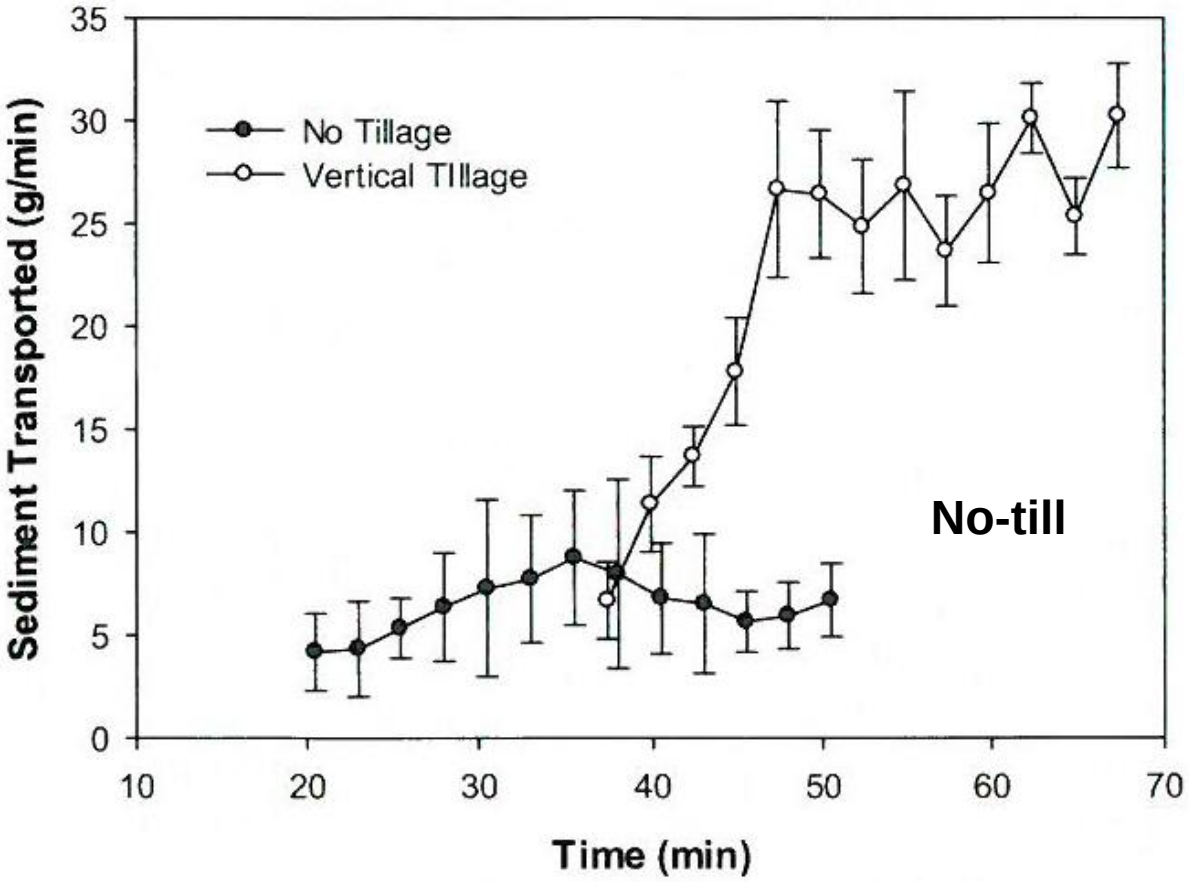
Vertical tillage

No-till

Fig. 2. Total phosphorus transported via runoff from no-tillage and vertical tillage plots. Error bars represent standard error.

Smith & Warnemuende-Pappas, 2015
Soil & Tillage Research 153:155-160

Sediment Runoff

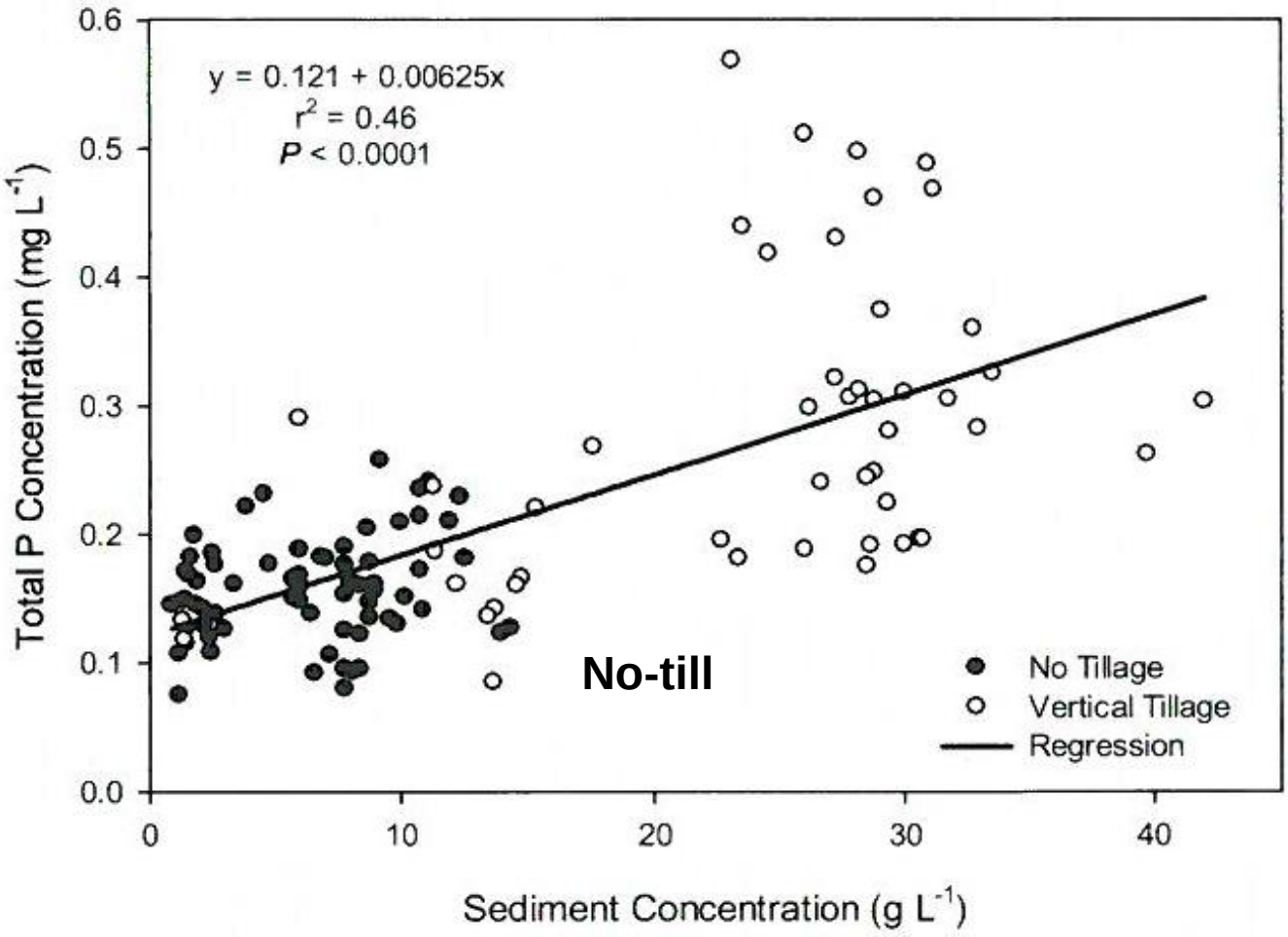


Vertical tillage

Fig. 3. Sediment transported via runoff from no-tillage and vertical tillage plots. Error bars represent standard error.

Smith & Warnemuende-Pappas, 2015
Soil & Tillage Research 153:155-160

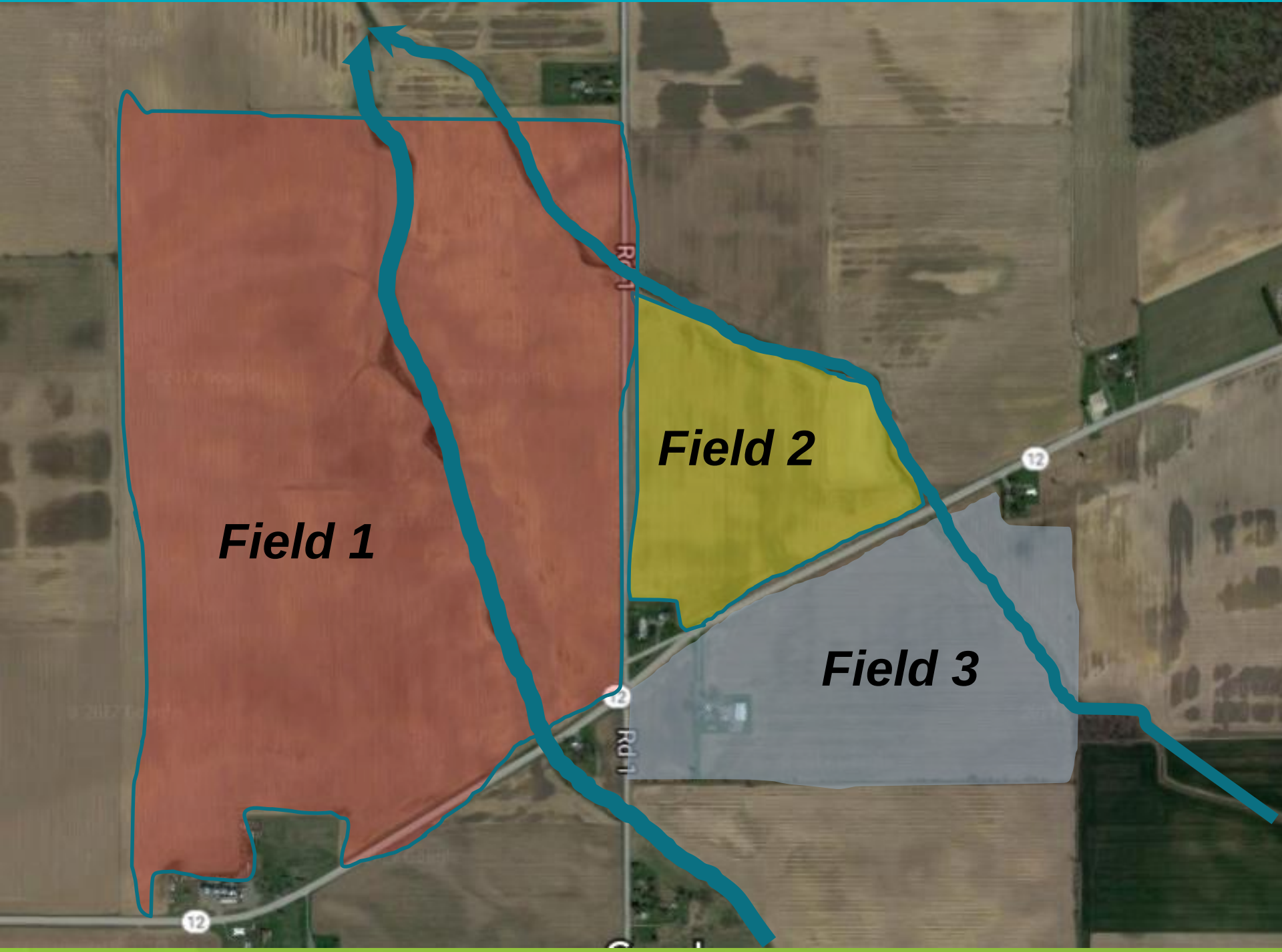
TP Concentration vs Sediment Runoff



Vertical tillage

Fig. 4. Relationship between total phosphorus and sediment mass transported during 30 min of runoff from no-tillage and vertical tillage plots.

Smith & Warnemuende-Pappas, 2015
Soil & Tillage Research 153:155-160


Field 1
Field 2
Field 3
Rd 1
Rd 1
12
12
12

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Field 1: Conventional

Entering stream/open ditch

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Field 1: Conventional

Open ditch splitting Field 1.
Notice the water level of the ditch.

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Field 2: Conventional

Field 3: No-till field with terminated cereal rye

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Field 3: No-till field with terminated cereal rye

Field 3: No-till field with terminated cereal rye


Field 3: No-till field with terminated cereal rye clear water entering muddy ditch.

Cover Crops for Absorbing SRP

Good Cover Crops

- Cereal rye
- Annual Ryegrass
- Triticale
- Barley
- Wheat

Mixtures/Minimize*

Radish*

Oats

Legumes

Other Issues

Short pasture

Alfalfa hay

When are the cover crops terminated?

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.
- Live roots absorb soluble nutrients (N & P).
- Increase soil organic matter content which improves soil structure and holds P tighter

  $SRP_i < EP_o$ and $FeP_i < Res\ P_o$
- Increased N & P uptake & storage means less runoff of N, P, and less soil erosion.

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