Keeping N and P out of Surface Water with Cover Crops

Why so much SRP in Surface Water?

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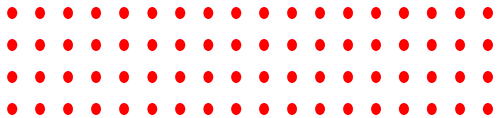
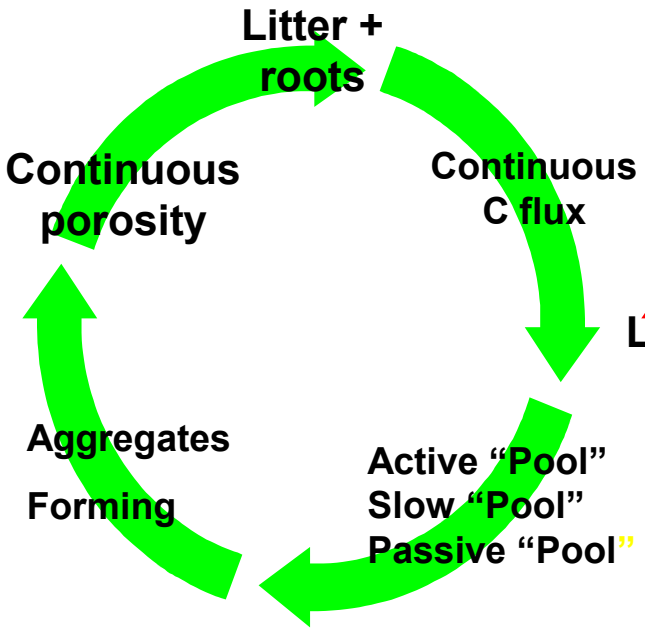
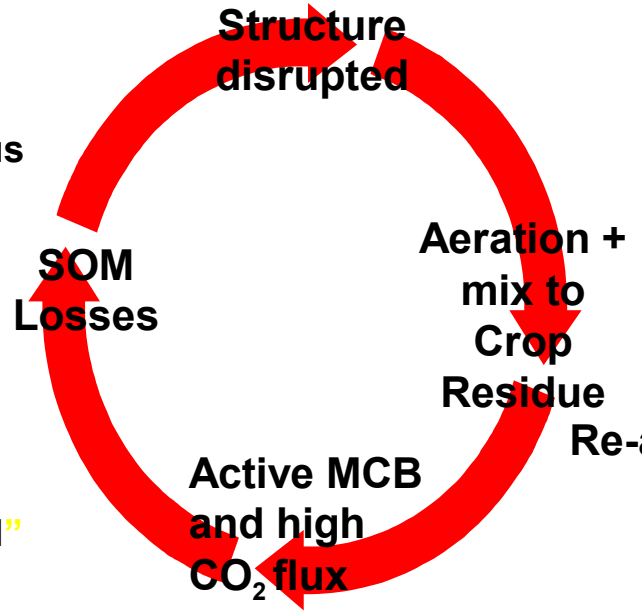
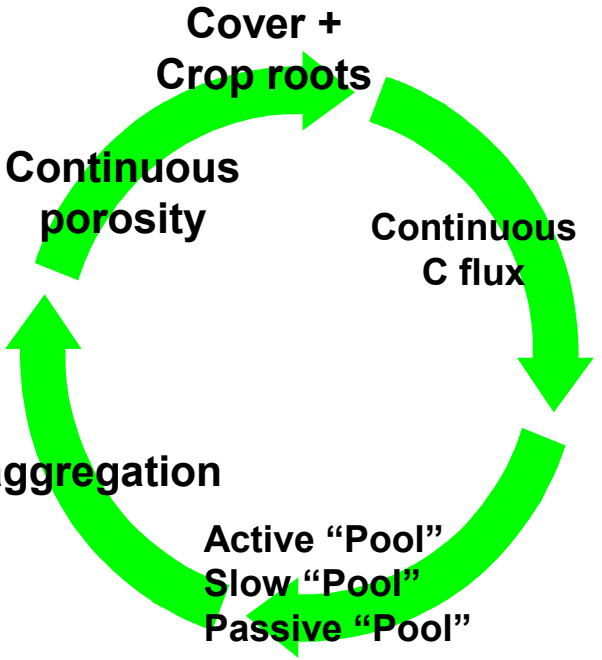
THE OHIO STATE UNIVERSITY EXTENSION

Basic differences among land systems









Soil Energy Comes from Plants

Conventional Tillage

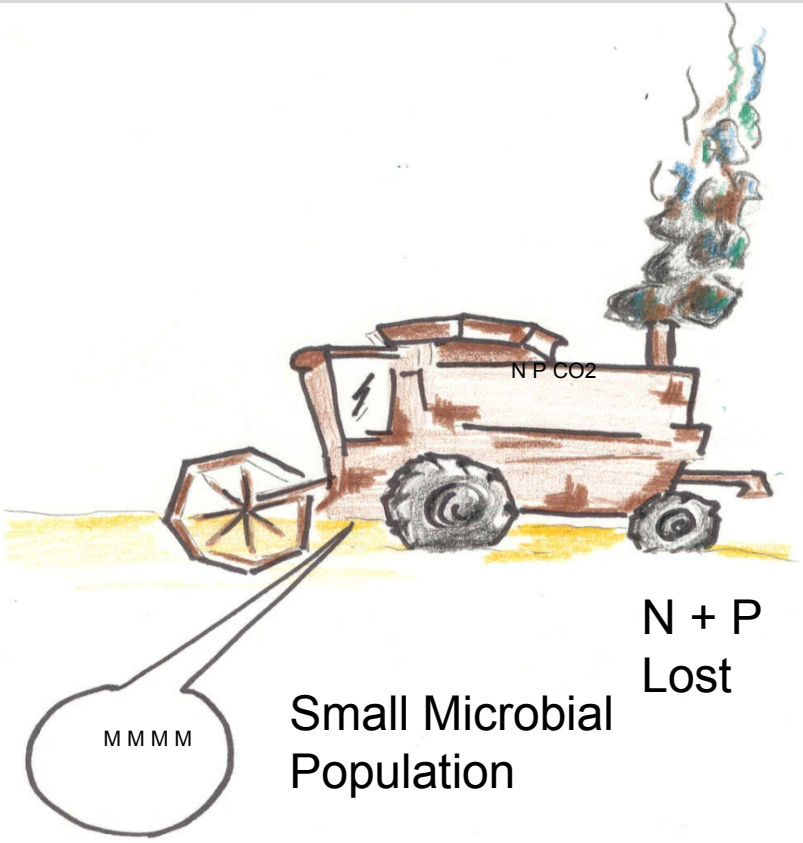
Plants 4 months out of 12 months
Fuel & Energy = 1/3 of time

No-till +Cover Crops "ECO Farming"

Plants 12 months out of the year
Fuel & Energy = 100% of time

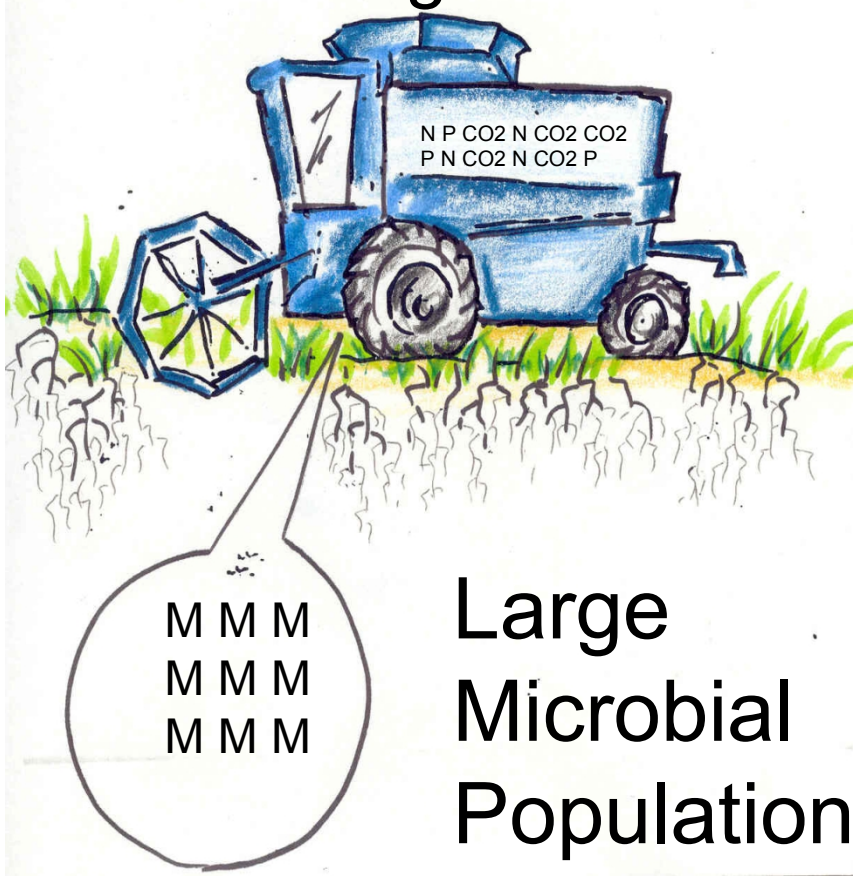
Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Soil Microbes Harvest & Recycle Nutrients



Conventional tillage

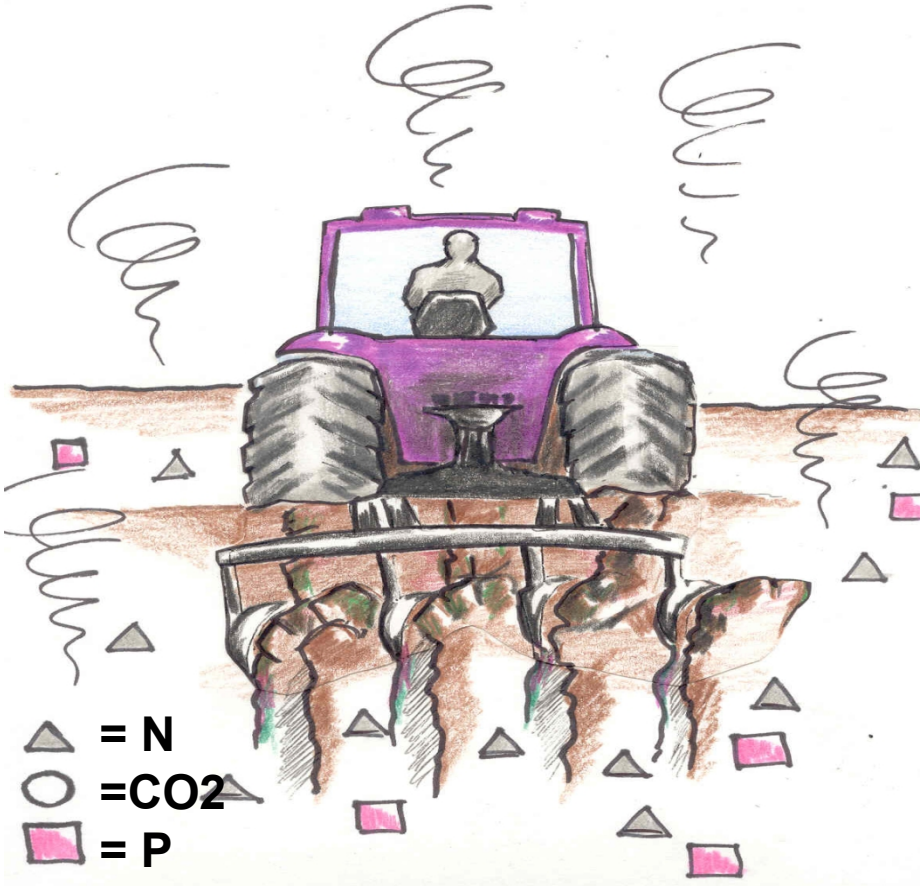
ECO Farming



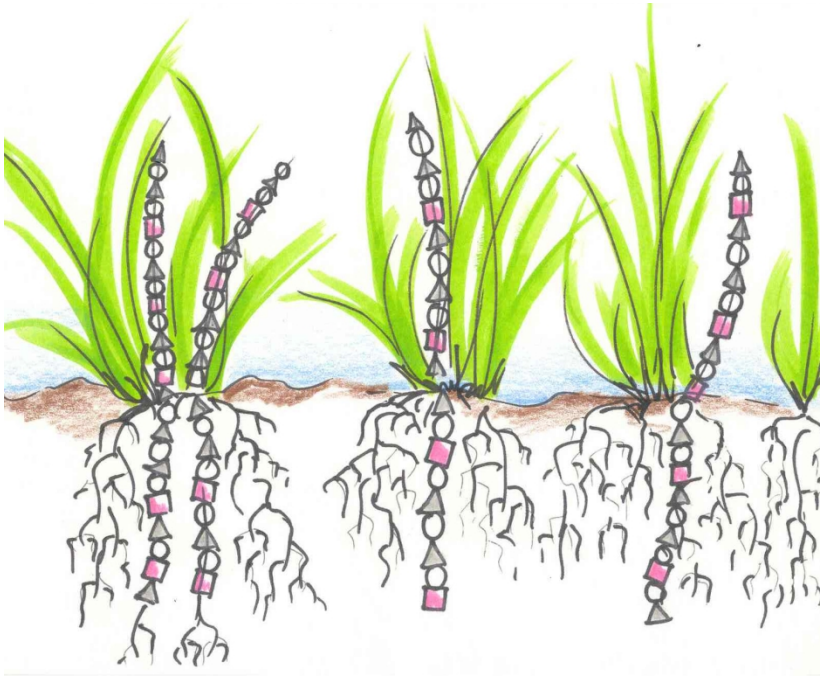
Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Tillage Burns Soil Organic Matter

Conventional Tillage



ECO Farming

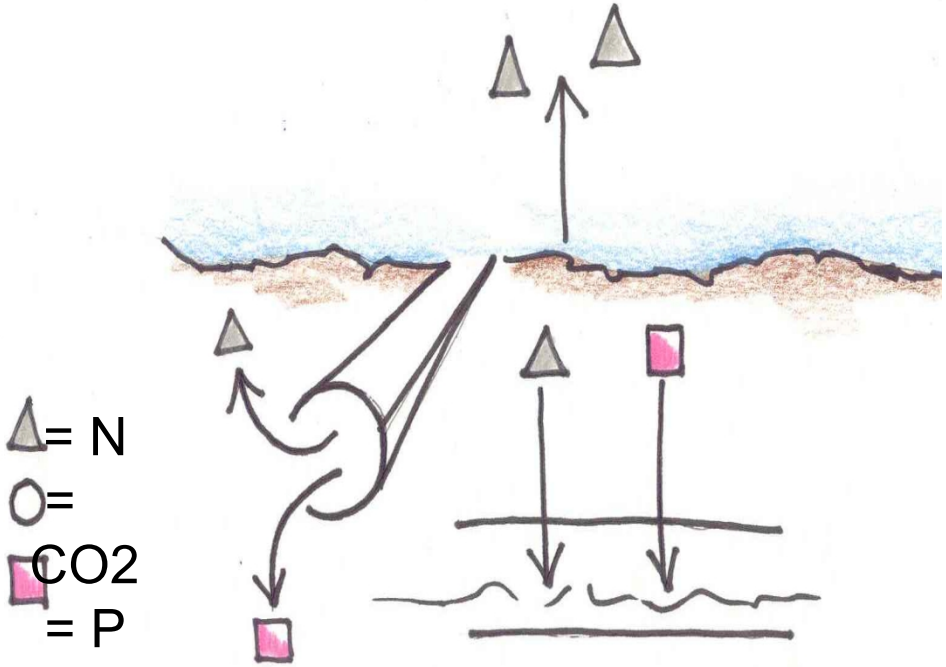


Nutrients (CO2, N, P) tied up in Plants.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Nutrient Fate in Winter and Spring

Conventional Tillage



Nutrients lost to air and water because no plant roots to absorb nutrients (N, P).

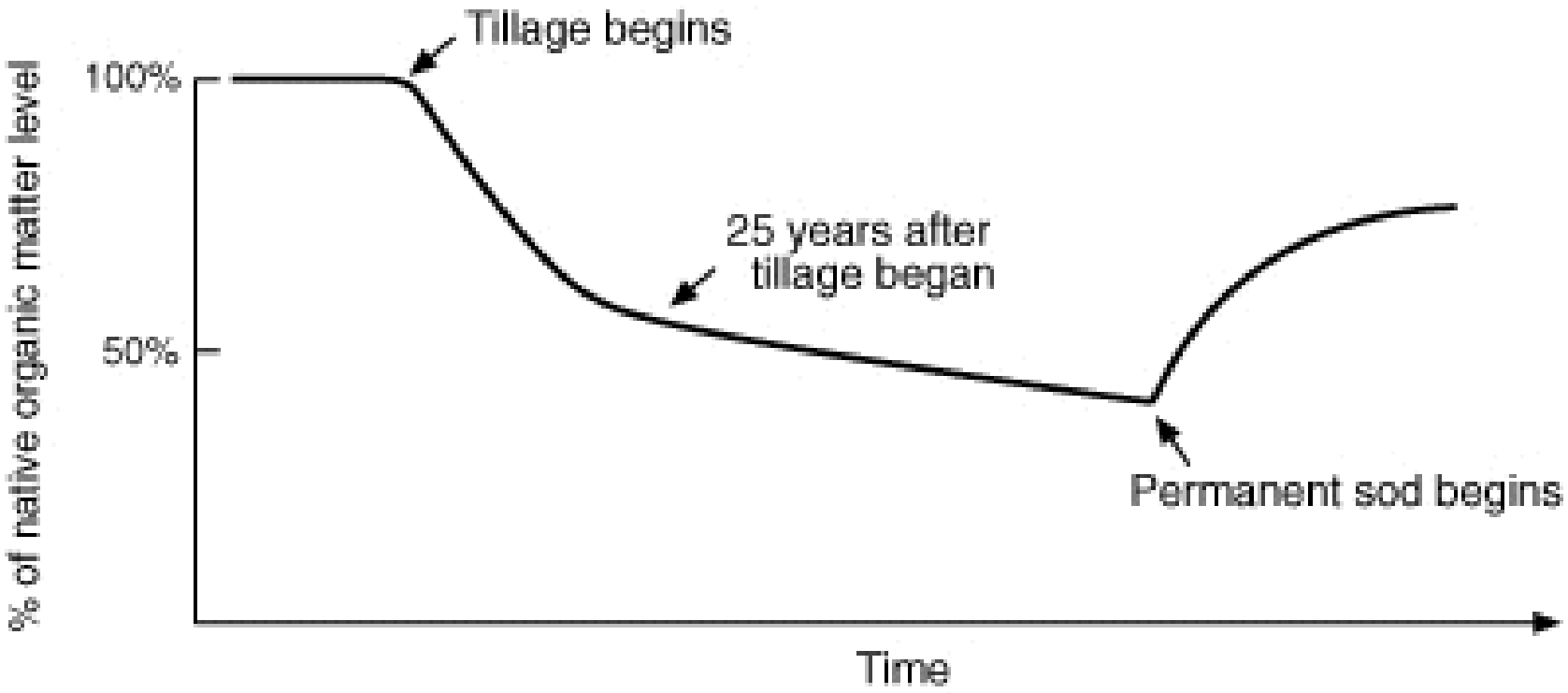
ECO Farming

Nutrients recycled in winter & spring & carried forward to next crop.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

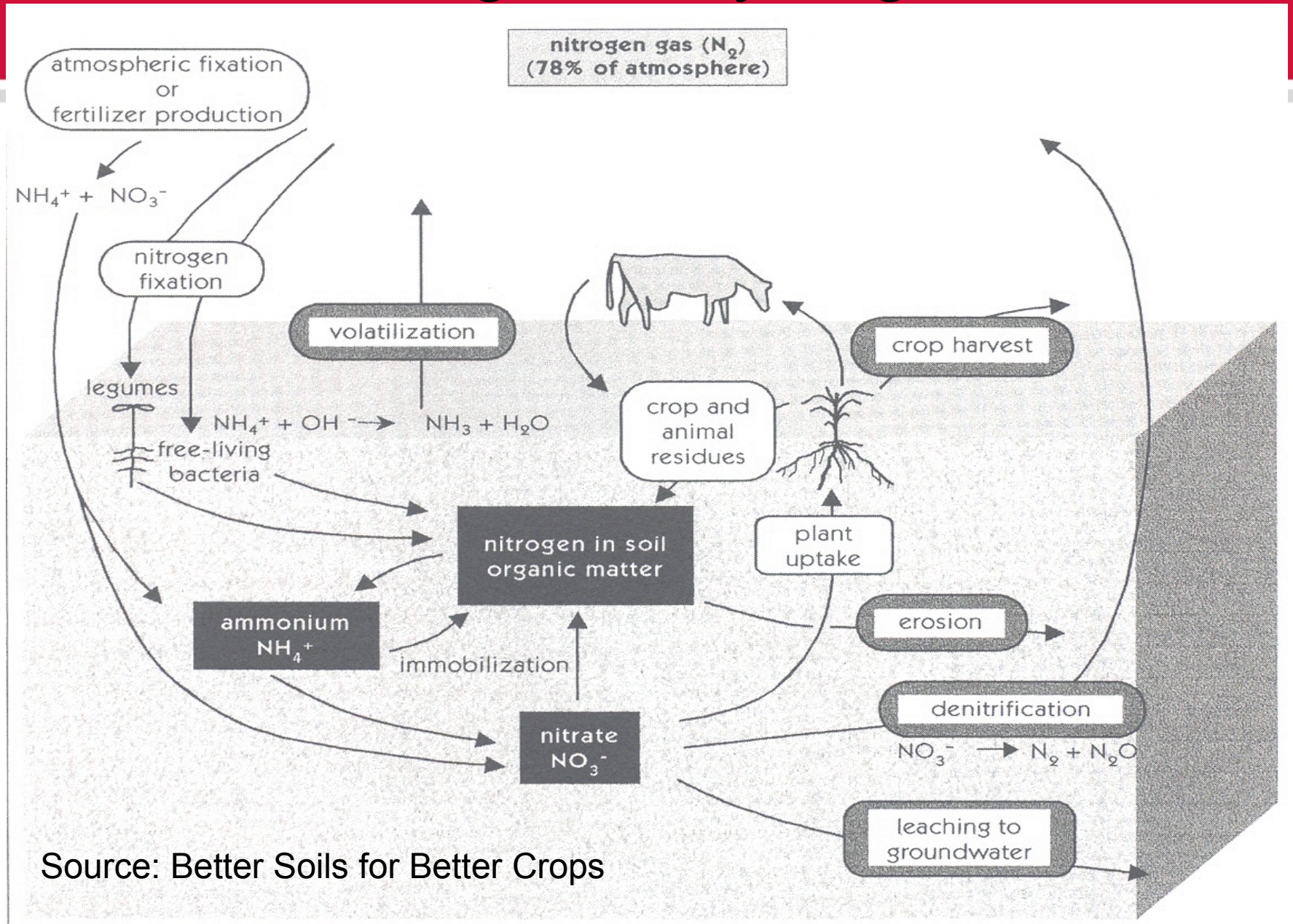
Soil Organic Matter Loss

Recent research



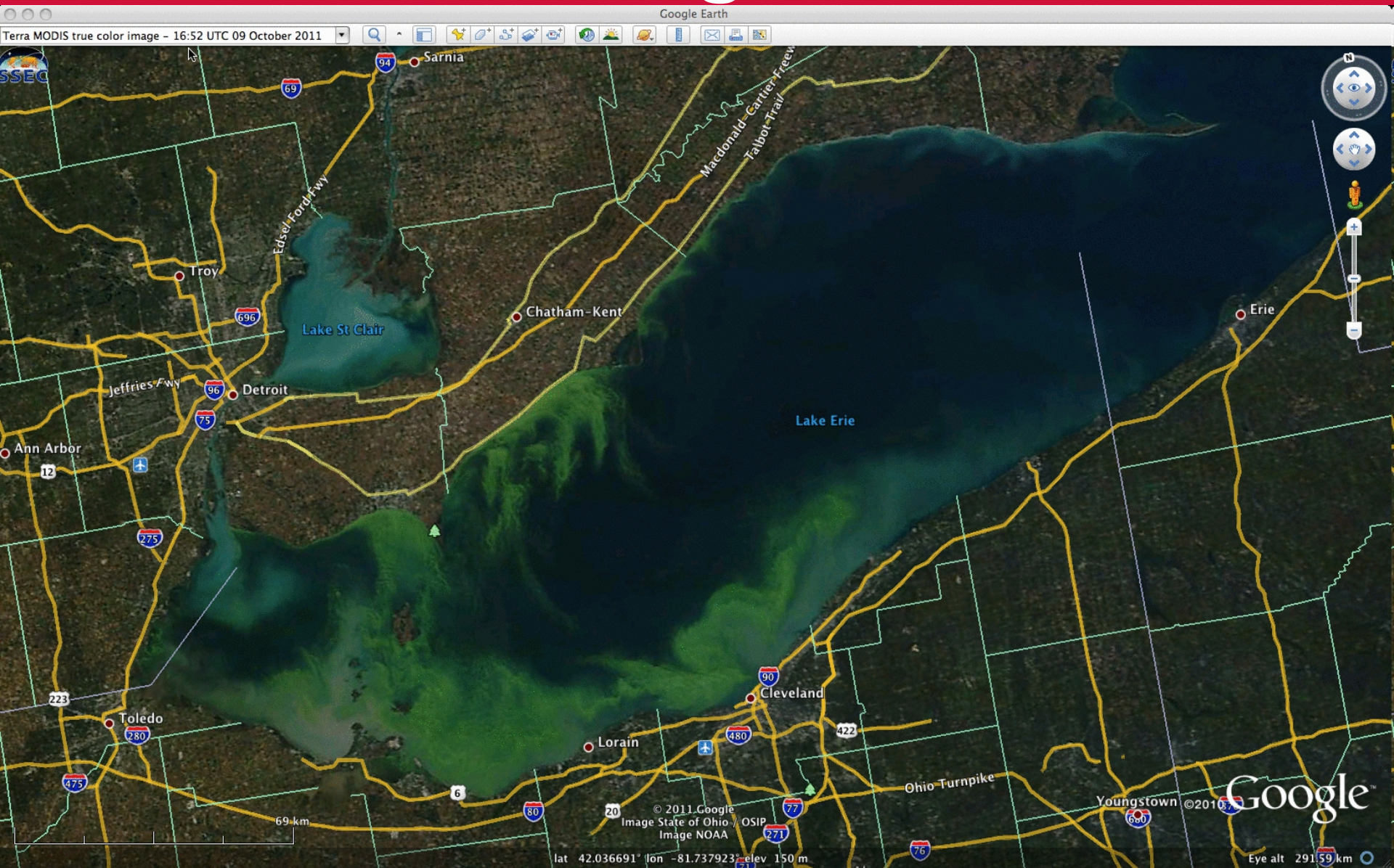
U of Minn

Nitrogen Recycling



Source: Better Soils for Better Crops

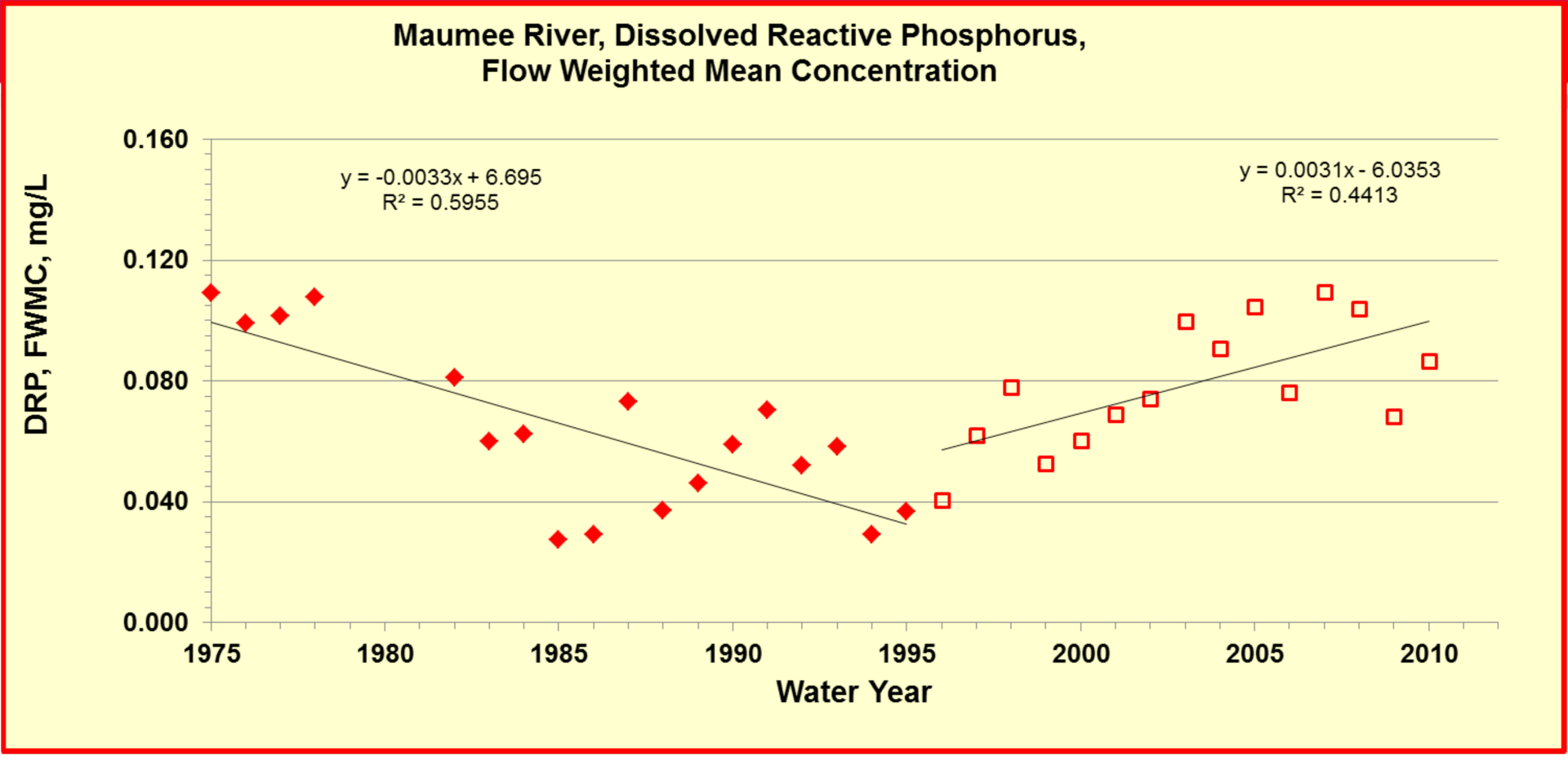
10/09/11 Image Lake Erie



July, 2011

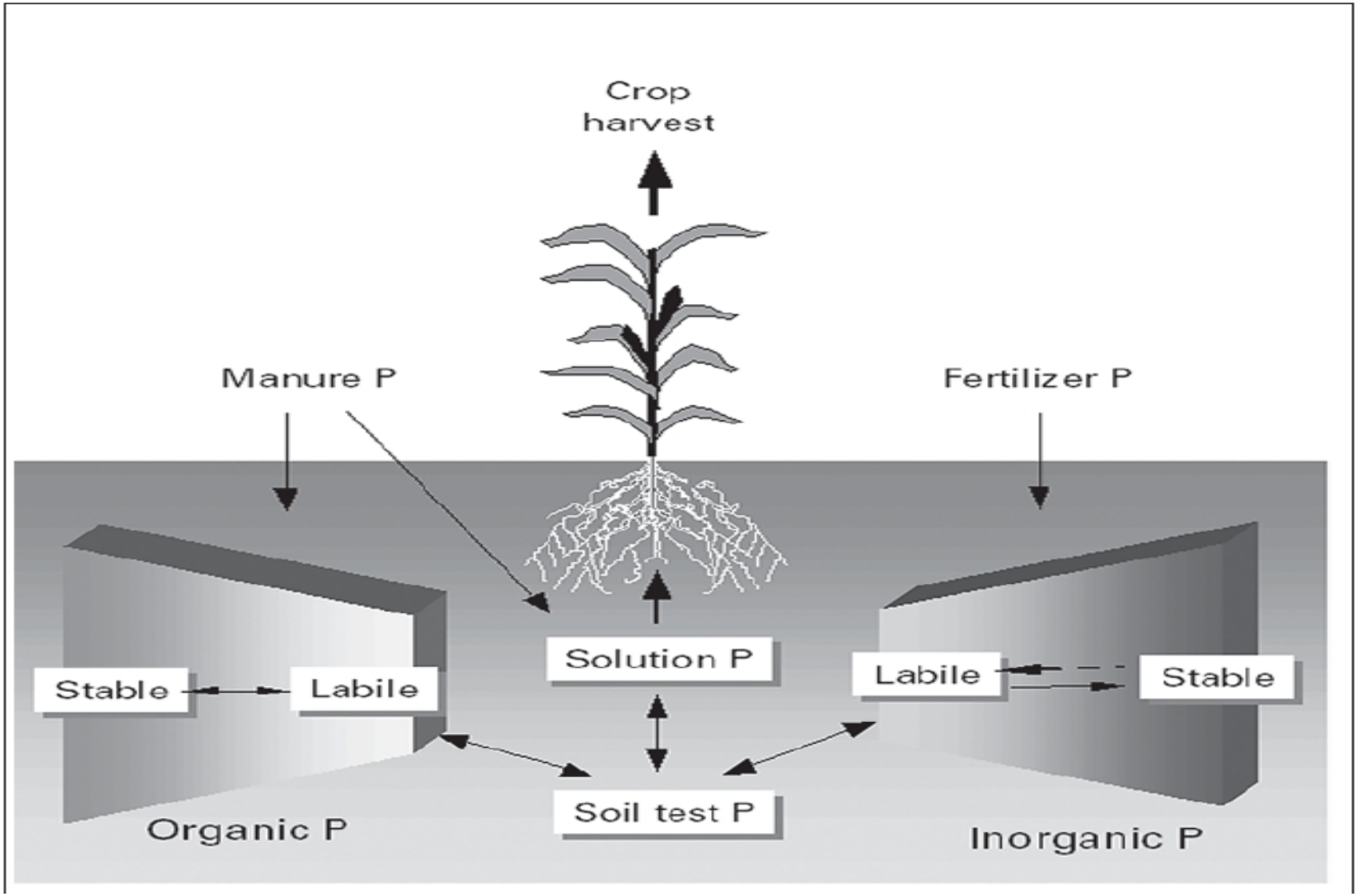
Source:http://www.glerl.noaa.gov/res/Centers/HABS/graphics/wle_hab2_%20072211.jpg

Grand Lake St. Marys 2010

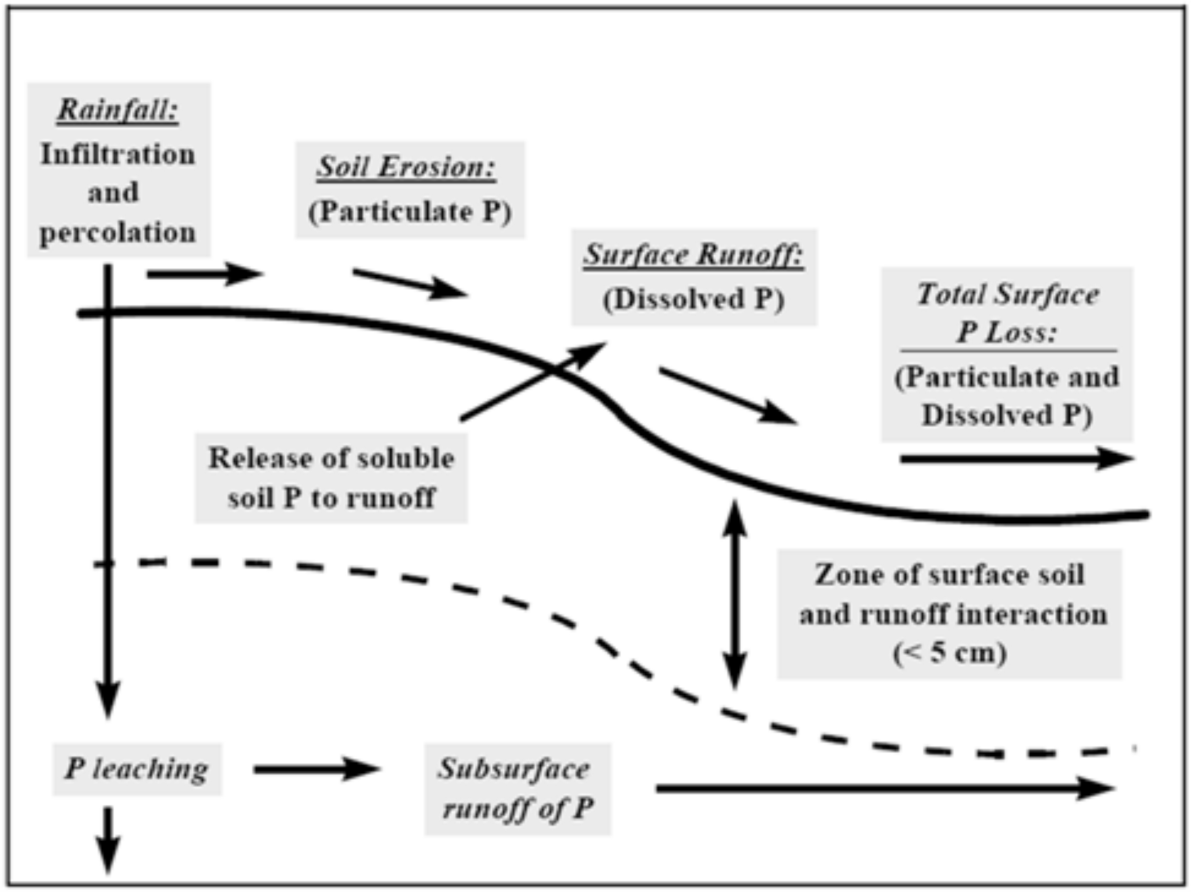


Source: Hiedelberg University

Phosphorus in Crop Production

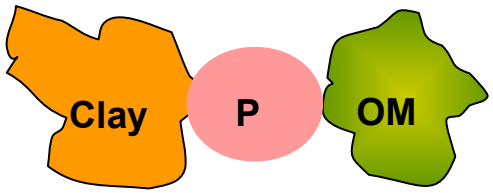


Phosphorus Losses to the Environment

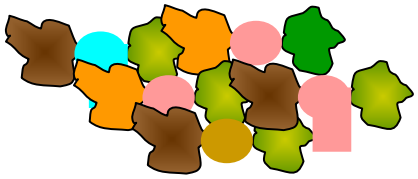


P stabilizes the OM and forms a bridge to the clay.

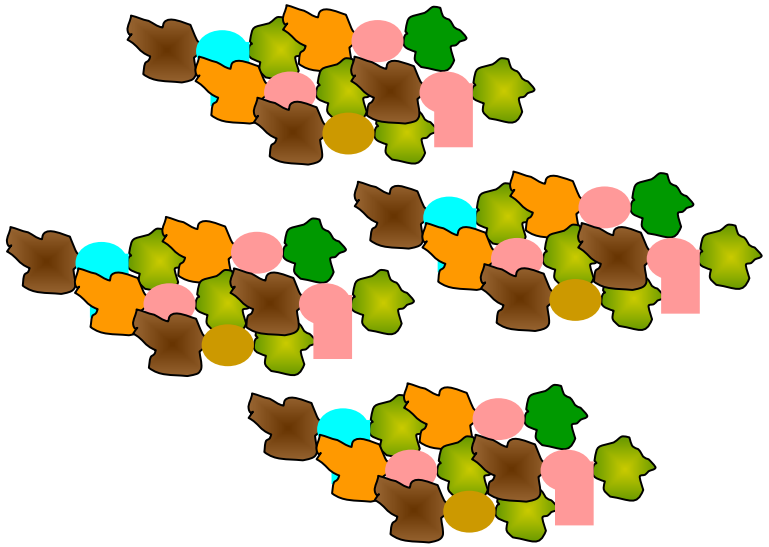
Our current P use efficiency is 10-25-50%.



Clay-P-OM



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



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

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
- 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.

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.
- Samples taken at following depths:

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

30 cm (12 inches)

Phosphorus Speciation: How Soil P is tied up

- Microbial – P_o P_o-Organic P
- Soluble Reactive (SRP) P_i P_i-Inorganic P
- Exchangeable (EP) P_o Active Carbon
- Ca^{2+} /Mg^{2+} Calcium/Magnesium
- Fe^{3+} /Al^{3+} Iron/Aluminum
- Res P_o Residual P_o-Humus
- Total P = All P_o + All P_i
- Murphy & Riley Standard P Extraction(1962)

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
- Concentration of P decreases with increasing soil depth.
- SRP and EP (which are easily plant available) are influenced by management practices and depth.

Phosphorus Speciation

Oxidized State	Reduced State
Iron (III) - Fe^{3+} (Ferric Fe) Yellow-Red	Iron (II) - Fe^{2+} (Ferrous Fe) Yellow-Grey
Manganese – MN^{4+} Pinkish Color	Manganese - MN^{2+} Grey-Black
Copper – Cu^{3+} Light Blue	Copper - Cu^{2+} Green

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

Ferric–P to Ferrous-P

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

$2*3=6^+ \quad 3*2^-=6^-$ $\qquad$ $2^+ = 2^- \quad 2*2=4^+ \quad 2*2=4^-$

Caused by Saturated Soil Conditions and Lack of Oxygen in top 2-3 inches of soil profile.

Flashiness in Streams causes two problems

1)Increases sediment high in clay and P

2)Less oxygen in top 2-3 inches of soil profile by holding water back. Chemistry of Rice Soils

Key Findings: Conventional Tillage vs Organic

- SRP and EP are significantly higher organic fields versus conventionally tilled fields.
- CaP and FeP, Res P, and Total P was significantly lower in organic fields versus conventionally tilled fields.
- SRP (0.63-0.83%) and EP (0.09 to 0.13%) are only a small percentage of the Total P.

Stratification of P by Tillage

- No major differences except in conventional tillage, FeP (1.5a) was significantly higher than organic FeP (1.2b).
- All other values including SRP, EP, CaP, Res P, and TP were not significantly different.

Conventional vs No-Till

SRP	EP	CaP	FeP	Res P	Total P
Conventional					
0.69b	**0.08a**	17.3a	27.5b	**133.7b**	**179.3b**
No-till					
0.93a	**0.19b**	16.9a	19.4b	**169.6a**	**208.2a**

No-till had significantly higher soil concentration of P in the SRP, EP, Res P, and TP fractions.

Conventional vs No-Till P Stratification

SRP	EP	CaP	FeP	Res P	Total P
Conventional					
1.3b	**8.4b**	1.4a	**1.5a**	**1.4b**	**1.4b**
No-till					
1.7a	**20.1a**	1.4a	**1.0b**	**1.8a**	**1.7a**

No-till had significantly higher soil stratification of P in the SRP, EP, and TP fractions but significantly lower FeP fraction.

Distribution of P by Crop Rotation

- SRP: Filter strips (4.76 a) + Forest (4.39a) > Alfalfa(2.60b) > c-s (.74c), c-c (.73c), s-s (.67c), c-s-w (.47c).

- EP did not vary much except c-s (0.03b), and s-s (0.02b) were significantly lower than others (0.28a).

Distribution of P by Crop Rotation

- CaP: c-s (31.4a) + c-c (27.6a) >

alfalfa (15.8b) + s-s (13.6b) + c-s-w (12.4 b) >

Forest (3.9c) + Filter (7.3 c)

- FeP: c-s (51.9a) + s-s (45.5a) >

  c-c (35.8b) + Filter (33.8 b) >

  c-s-w (12.5c) >

  Forest (2.6d) + Alfalfa (7.3d)

Distribution of P by Crop Rotation

- Total P: s-s (232.5a) >

c-s (207.9b) + c-c (192.7 b) +Filter (191.5b)
c-s-w (189.9b) + Alfalfa (184.9b) >

Forest (165.0c)

What is characteristic of soybeans? High P demand, Lower SOM and fewer roots!

Key Findings: Crop Rotation

- SRP was significantly higher in Vegetative Locations than in fields with annual crops. Why? Is it due to less SOM? Is it due to more P runoff? Or do crops absorb more P?
- Why is the highest CaP and FeP found under crop land?
- EP does not vary significantly except on s-s (.02b) and c-s (.03b) rotations (c-s-w, .14a) where it was lower. Soybeans require P!

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 Strip	**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

Key Findings

- SRP and EP stratification of P highest under Filter Strips and Forest.
- However, CaP highest under c-c and c-s.
- FeP highest under c-s and s-s, crop rotations probably due to soybeans and high acidity.
- Forest and alfalfa had the lowest FeP stratification. Note higher FeP under filter strips. Why?

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), Res P, and Total P but much higher EP (8.8X), CaP, and FeP.

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.

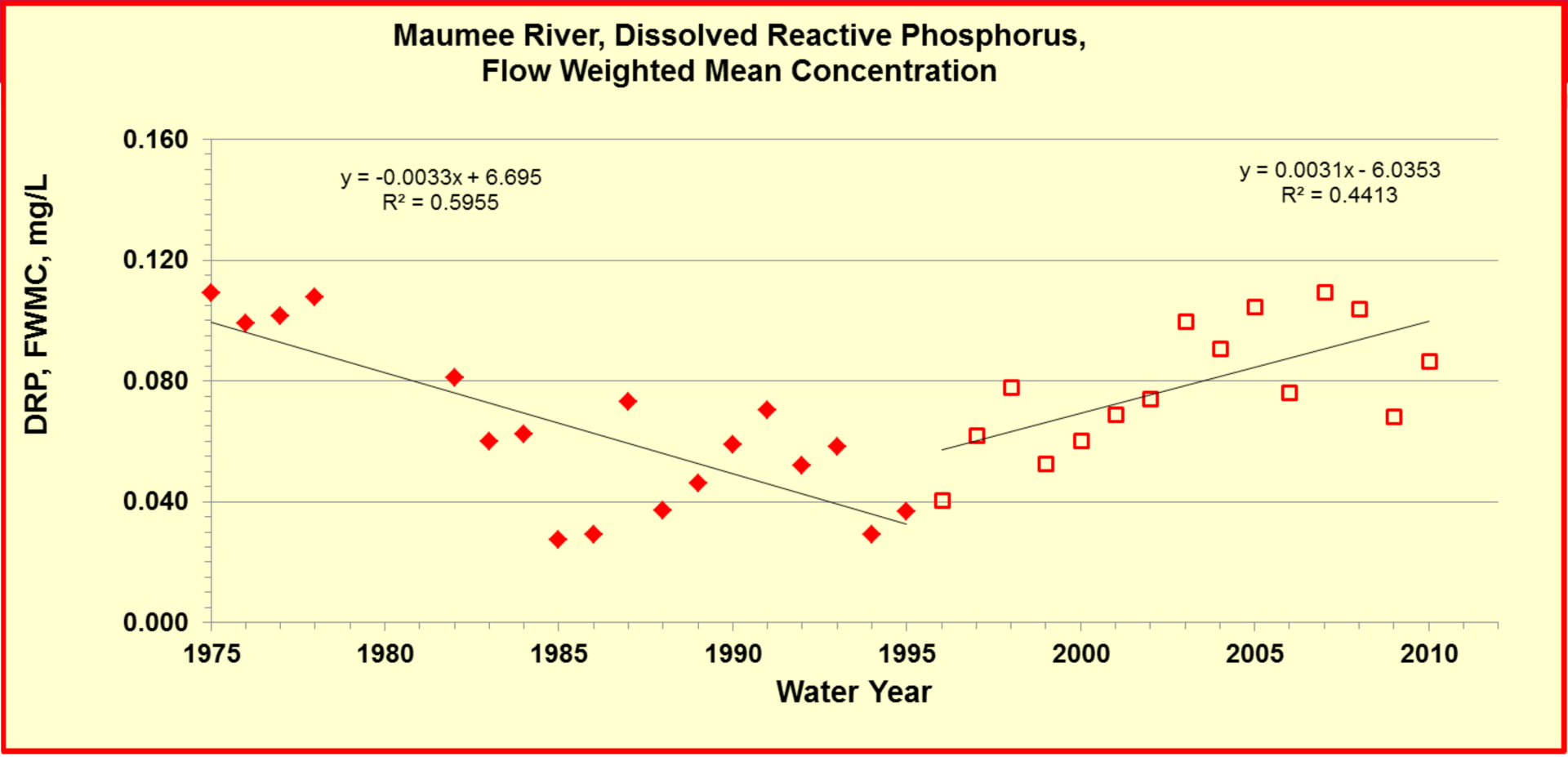
Long Term No-Till vs. Rotational Tillage

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

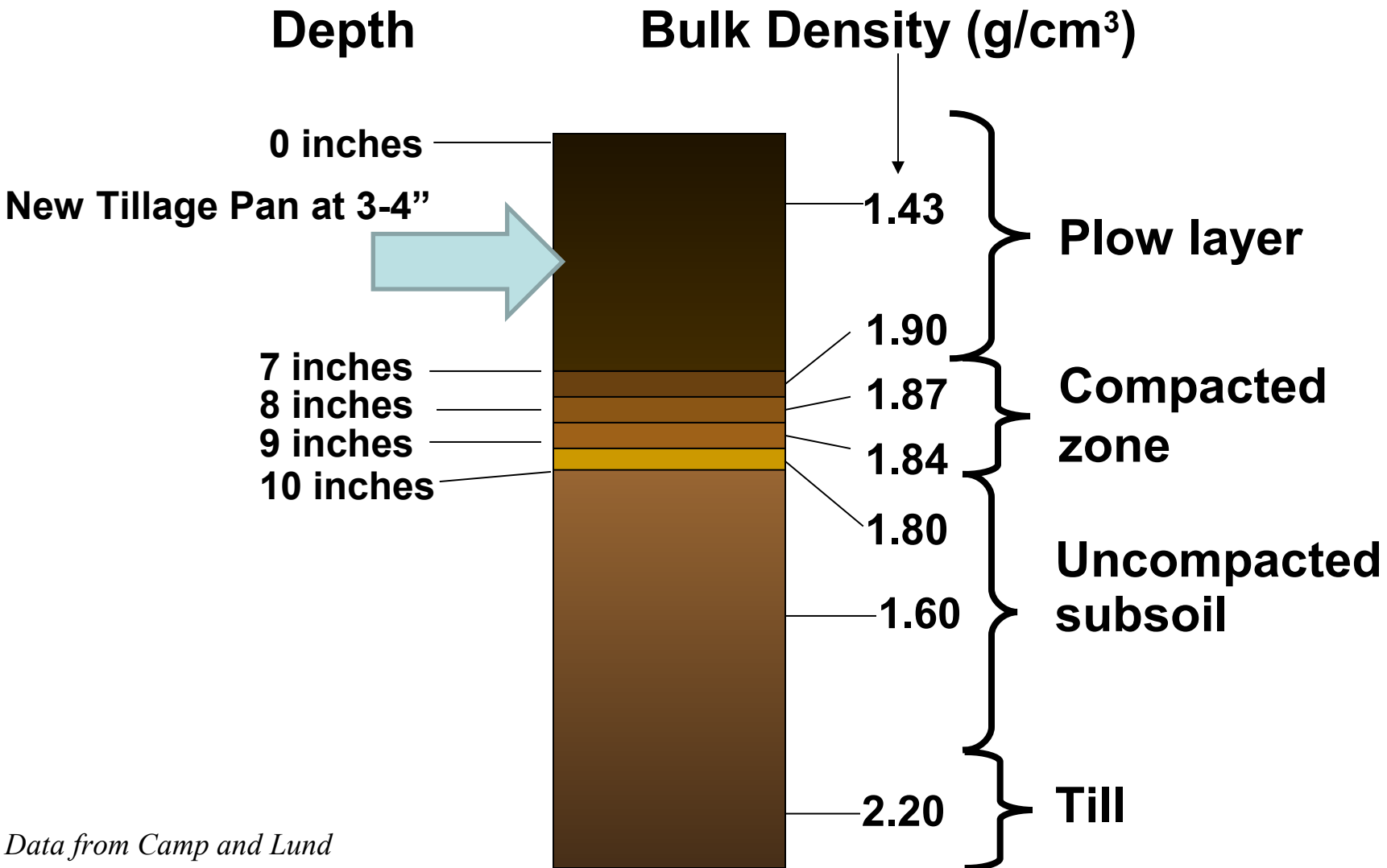


Source: Hiedelberg University

What changed in AG since 1995

1) More Conservation Tillage – less soil mixing of P in top 2 inches.
2) Larger Equipment – More Soil Compaction
3) Crop rotations – Less wheat, more beans/ beans
4) More tile-Spaced closer together, more surface inlets.
5) Fertilizer Enhancers (Avail/Jumpstart)
6) Less Soil Organic Matter

Bulk Density and Compaction

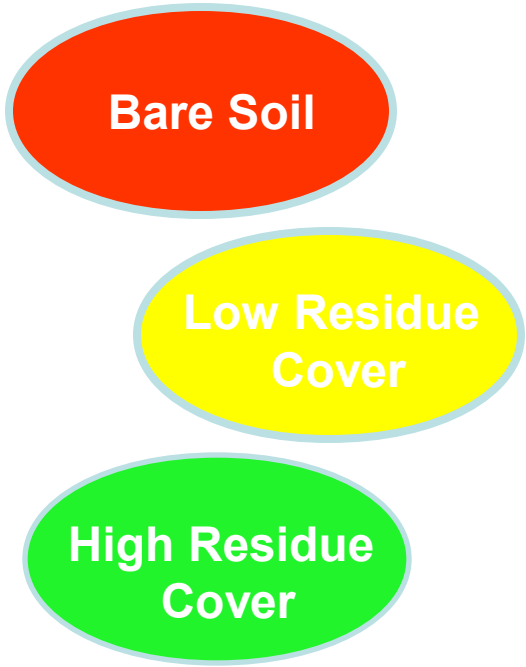


Data from Camp and Lund

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

Saving Nutrients in the Soil

…is related to the speed of Water!

If the velocity of water is doubled how many more nutrients travel in a stream with the water?

2^6 = 64 times more nutrients lost!

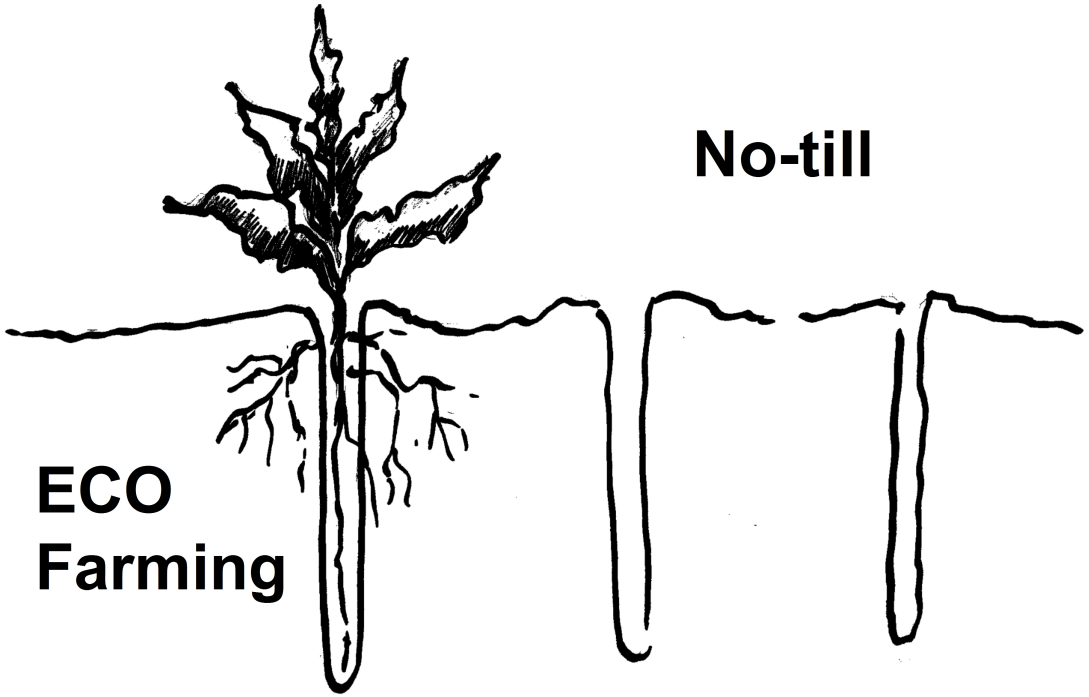
1	to	2 mph	64x
2	to	4 mph	128x
4	to	8 mph	256x
8	to	16 mph	512x
16	to	32 mph	1,024x

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 $FeP_i < Res\ P_o$

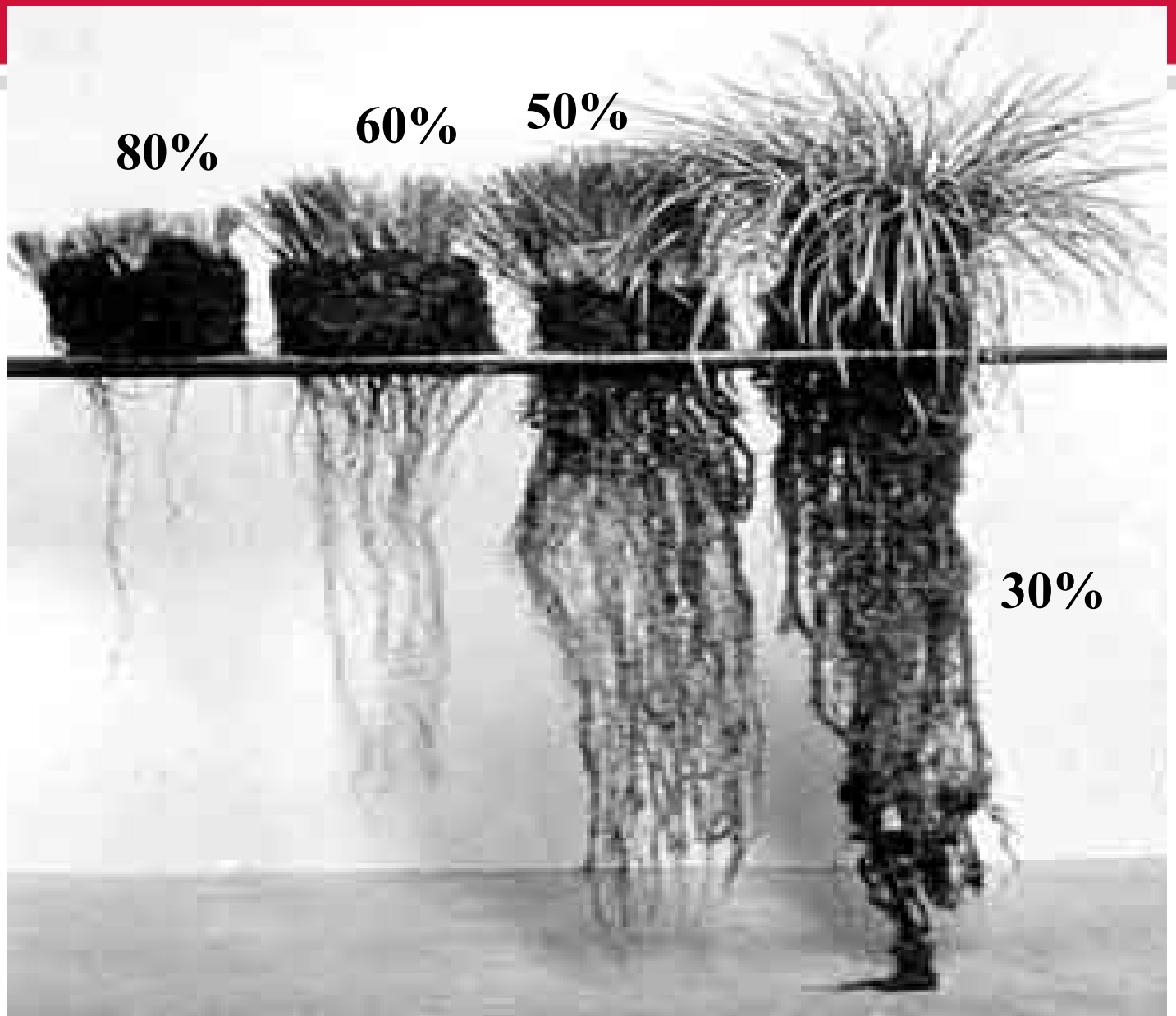
N0-TILL creates macropores



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



Additional Facts about FeP

- FeP_i Mediated or changed by soil microbes (Hedley, 1982)
- FeP_i can be reservoir of P when soil P is low (Kuo, 2003; Zhang 1997) and is considered to be plant available (Zhang, 1997).
- At high fertilization, SRP_i can easily be converted to FeP_i (Kuo, 2003; Zhang, 1997).

Cover Crops and Phosphorus Speciation in Ohio

Why so much SRP in Surface Water?

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THE OHIO STATE UNIVERSITY EXTENSION

Continous Corn –No Fertilizer

Year	SRP	CaP	FeP	Res P	Total P
1988	150	1390	**233a**	330	**722a**
1993	129	1357	**187b**	287	**623b**

- Five year study on Rosalie Clay soil in Canada (Zhang, 1997)
- CaP remained constant for all 5 years even when 44 and 132 kg P/ha added as fertilizer.
- FeP acted as soil reservoir for P, releasing P_i when SRP was low and absorbing P_i when SRP was high.

Additional P_o Facts

- About 1% of soil organic P is released each year (Hedley, 1982, Zhang, 1997).
- About 56% of soil P in Res P_o. This fraction remained constant on fertilizer plots but decreased 14% on unfertilized plots.
- P_o is a major source of Plant P when SRP_i is limiting and they found that inadequate SRP_i may deplete P_o more than P_i sources (Tiessen et al, 1984).

Additional P_o Facts

- P_o released to P_i is dependent on the release of phosphatase enzymes in response to low P_i availability and is related to root activity and soil microbes (Tiessen et al, 1984).
- Kuo, 2003 found that once an undisturbed soil is tilled or turned under, P_o is mineralized quickly to P_i but then P_o is limited? Why (Lost as carbon dioxide in air.)
- CaP may also be transformed to P_o by soil microbes but this process is more limited.

Additional P_o Facts

- Chauban et al, 1981 found that additions of cellulose stimulated microbial activity and they presumed that P_1 was immobilized as P_o.
- Hedley, 1982 found that soil P_o was increased in a P rich soil with additions of SOM and P fertilizer, however; in a P deficient soil, additional SOM and P fertilizer are required before any buildup of P_o occurred.