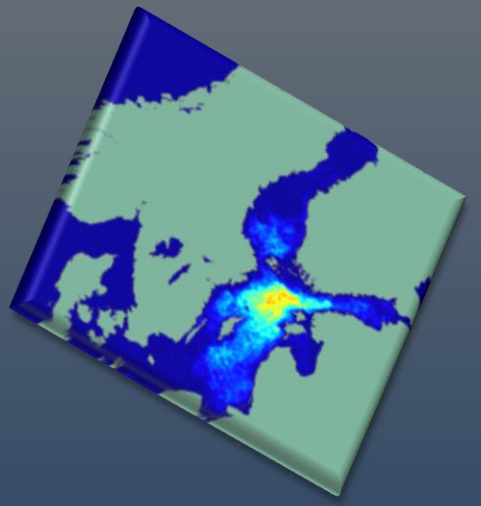
Phosphorus in a global context

Persistent issues in research and management



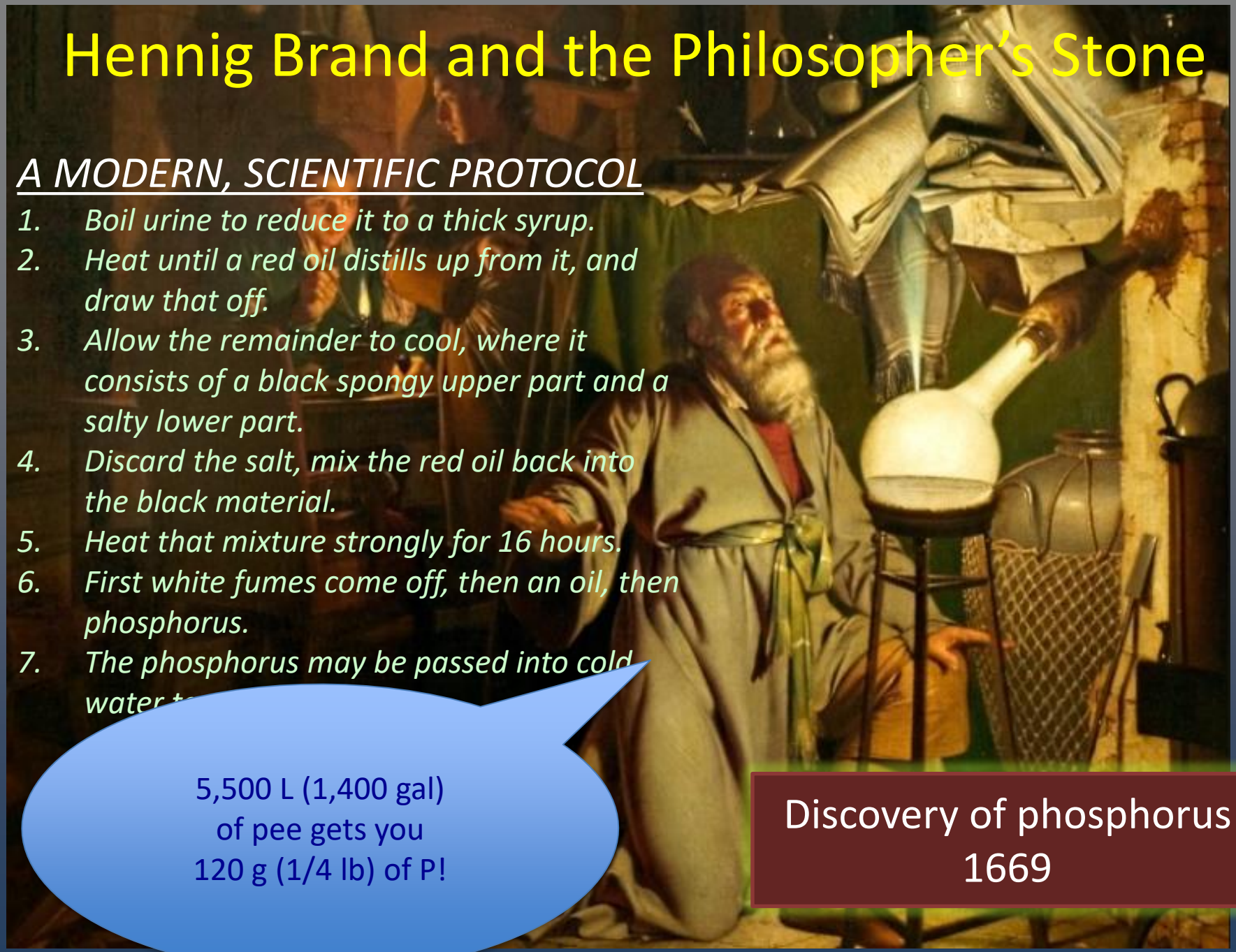
Peter Kleinman

U.S. Department of Agriculture

Agricultural Research Service

Understanding Algal Blooms: State of the Science
September 13, 2018. Toledo, OH.

Hennig Brand and the Philosopher's Stone



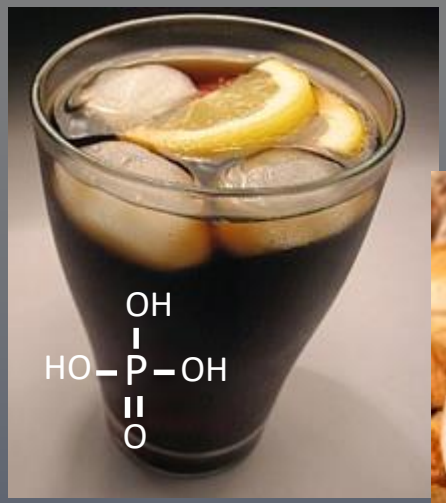
A MODERN, SCIENTIFIC PROTOCOL

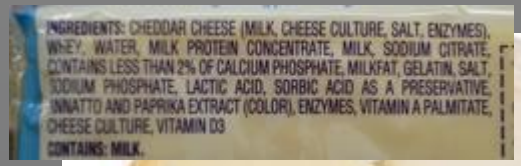
1. *Boil urine to reduce it to a thick syrup.*
2. *Heat until a red oil distills up from it, and draw that off.*
3. *Allow the remainder to cool, where it consists of a black spongy upper part and a salty lower part.*
4. *Discard the salt, mix the red oil back into the black material.*
5. *Heat that mixture strongly for 16 hours.*
6. *First white fumes come off, then an oil, then phosphorus.*
7. *The phosphorus may be passed into cold water t*

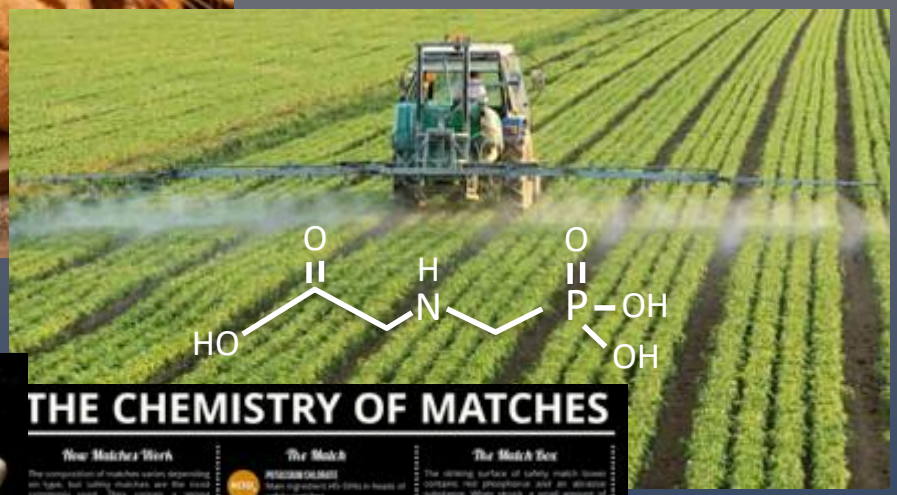
5,500 L (1,400 gal)
of pee gets you
120 g (1/4 lb) of P!

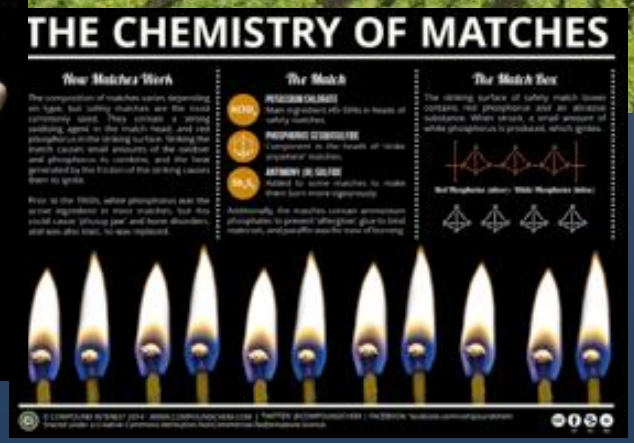
Discovery of phosphorus
1669

Devilishly useful



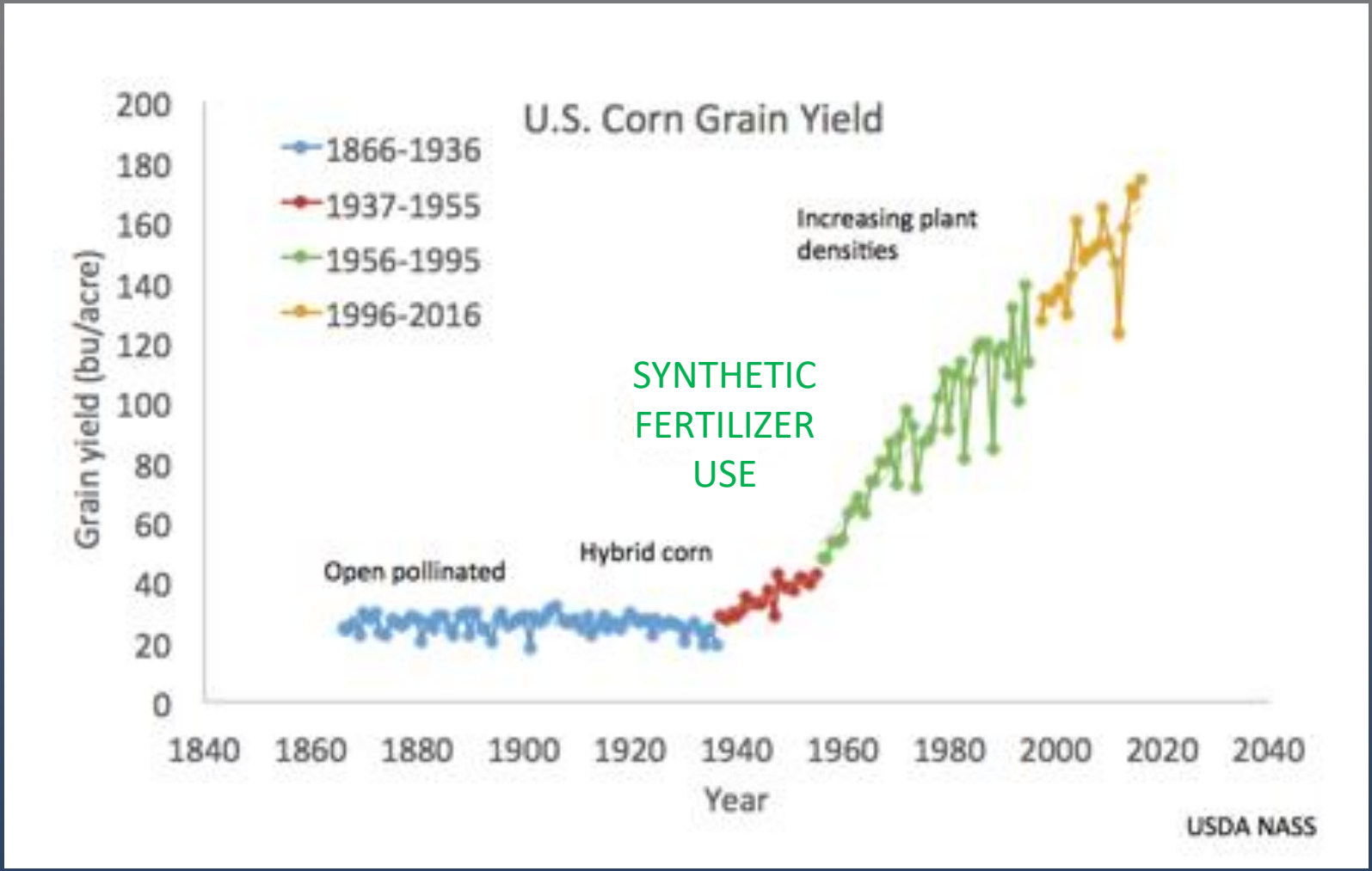






Phosphorus as a crop nutrient

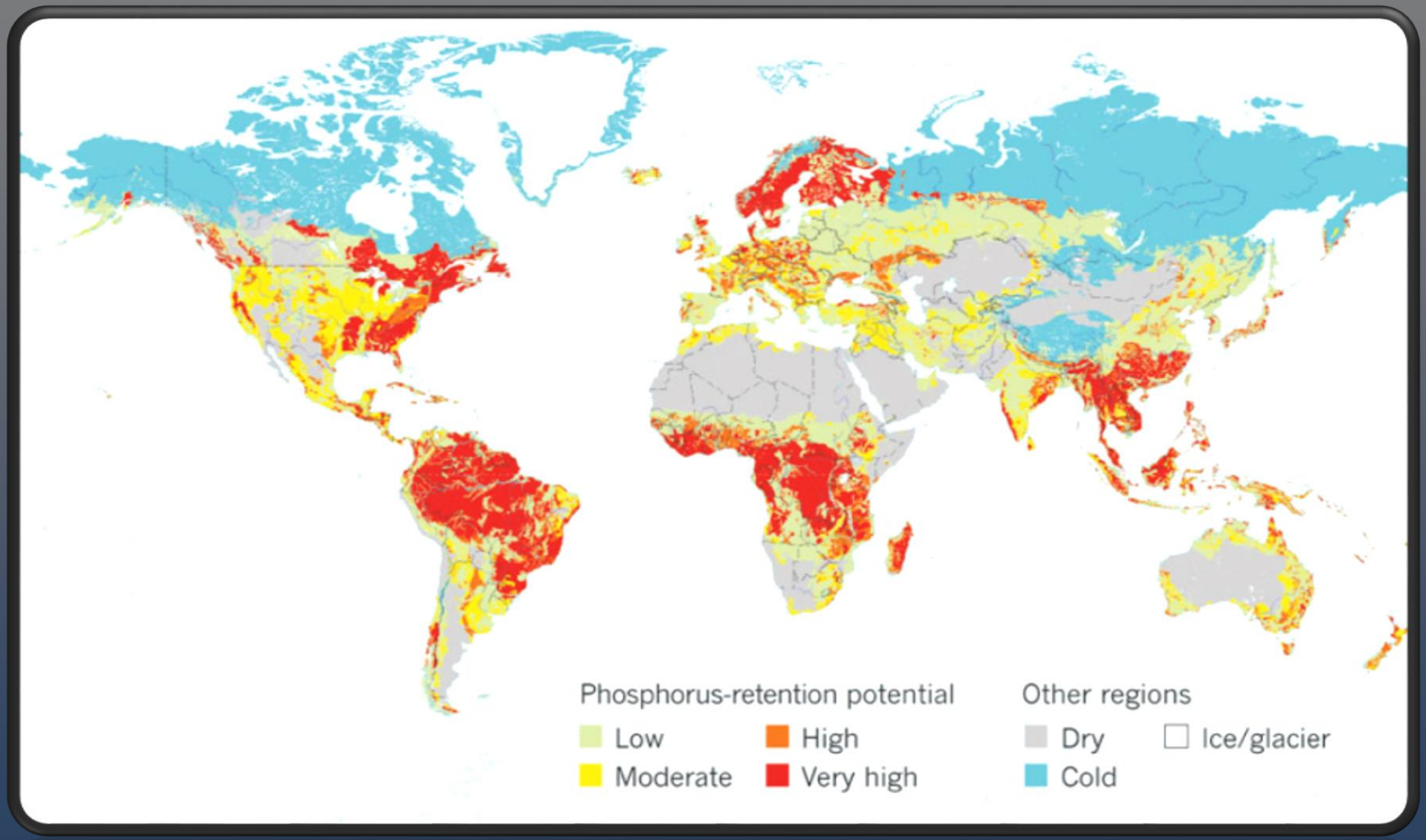
A pillar of modern crop production



Courtesy H. Poffenbarger.

Challenge: the inequity of resource distribution

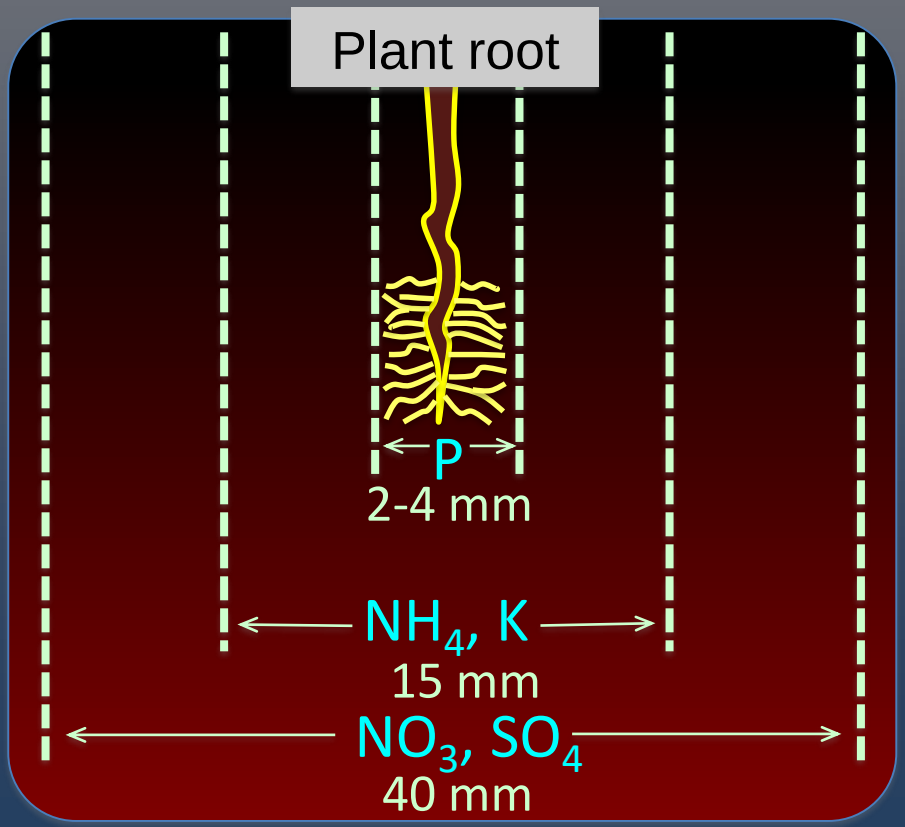
Overcoming soil P buffering

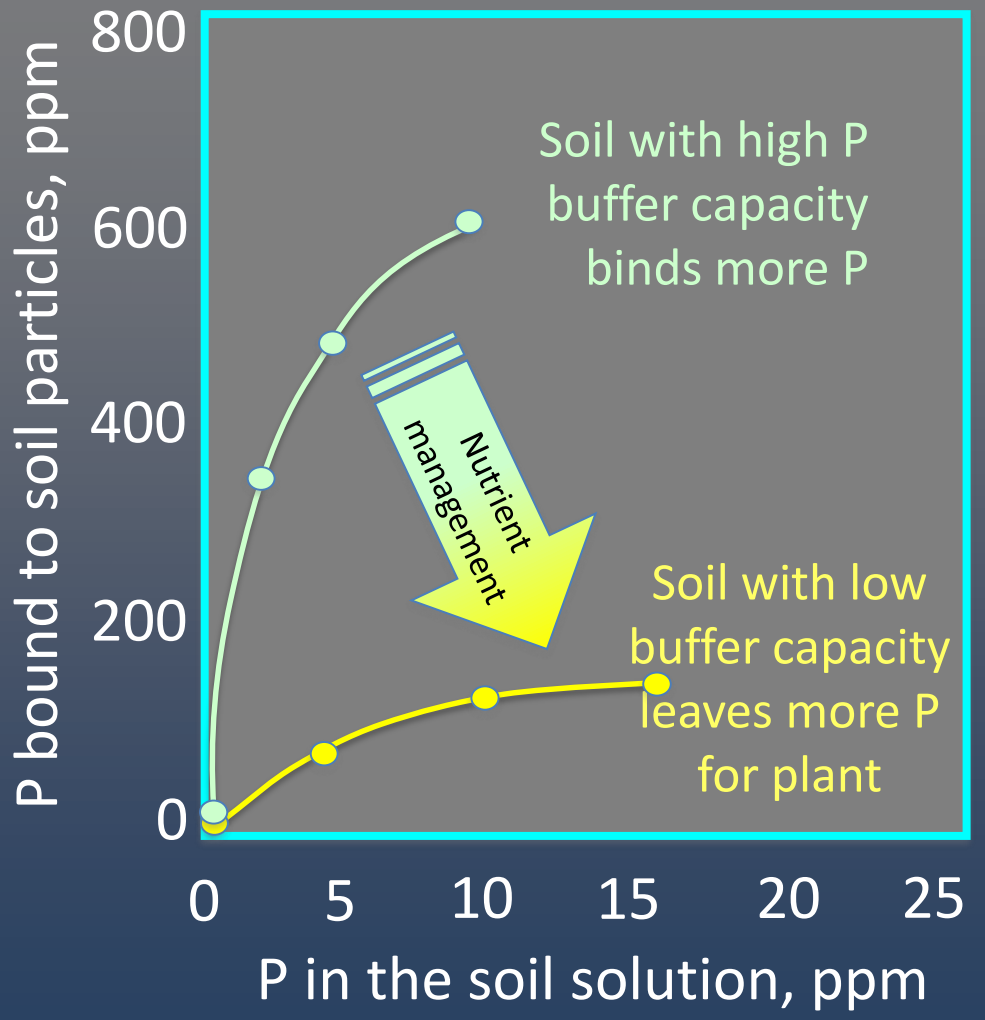


Kochian: Nature, 2012

Phosphorus fertility - historical priority

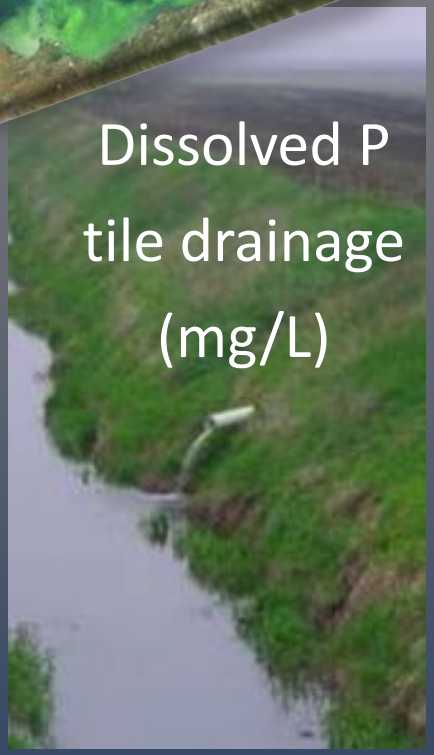
Fertilizing the soil to get to the crop

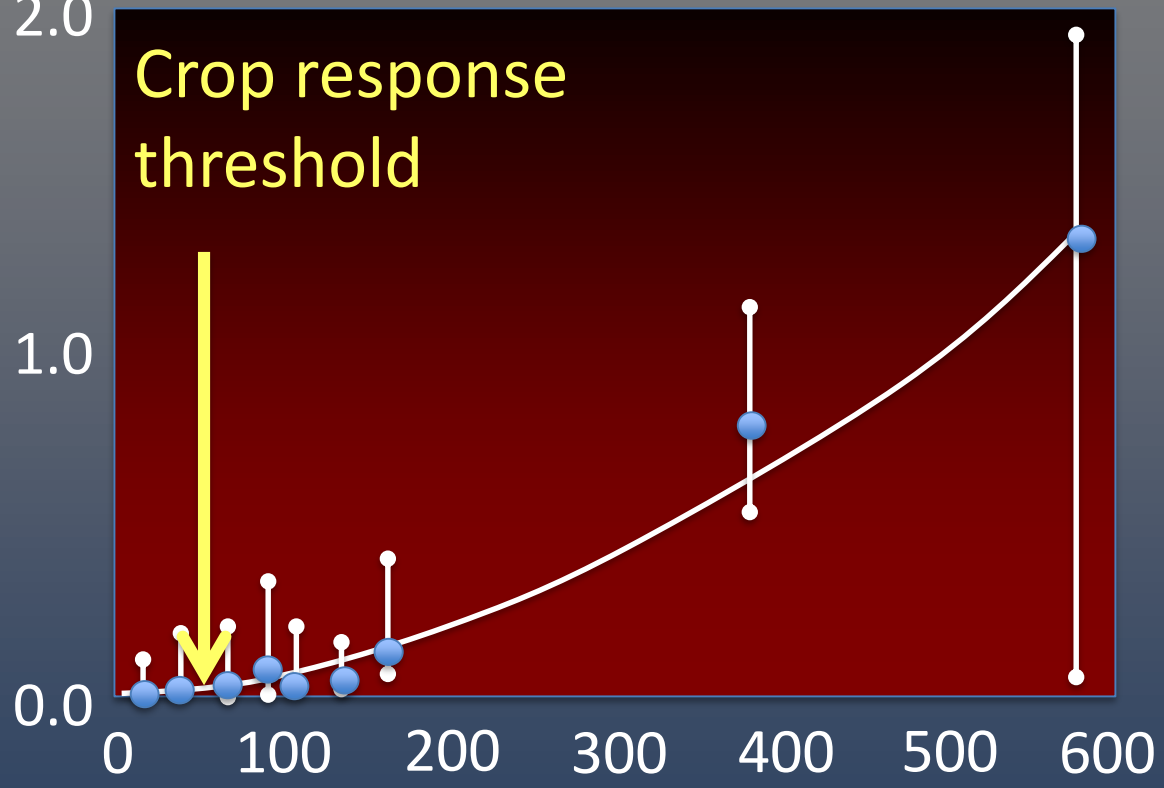


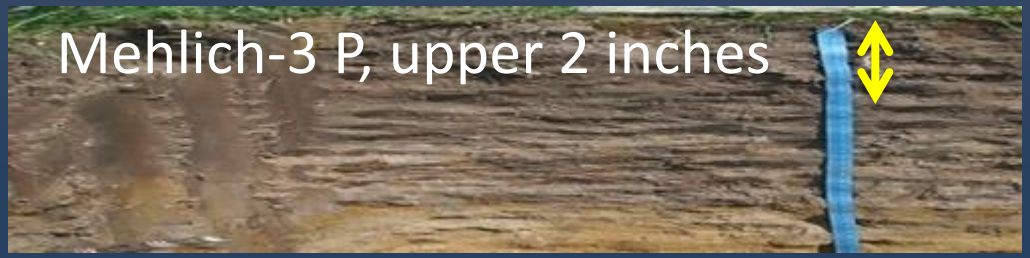


Inherently inefficient

P loss to water



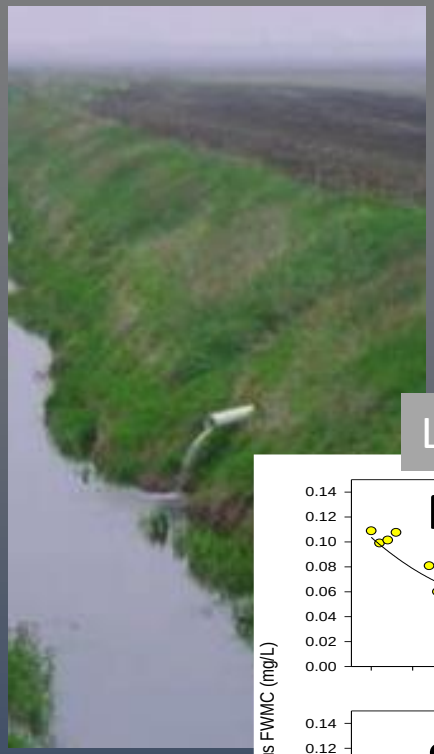




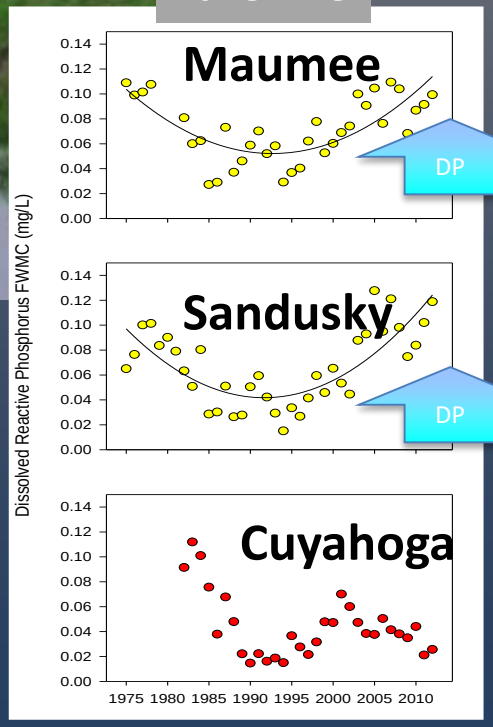
Source: King, USDA-ARS

Dissolved P - the universal headache

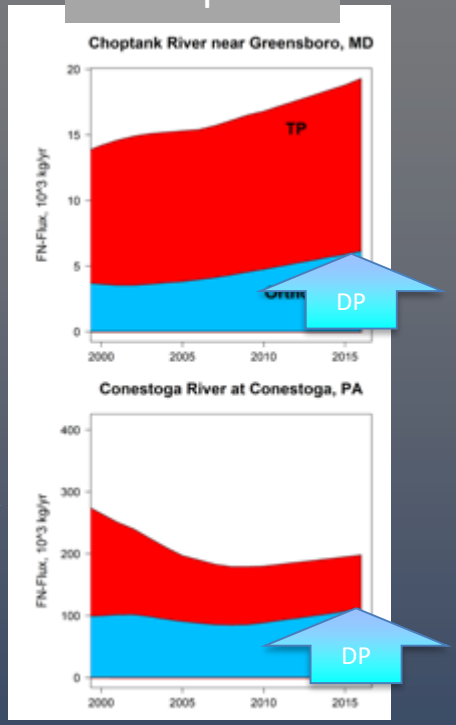
aka “soluble P”



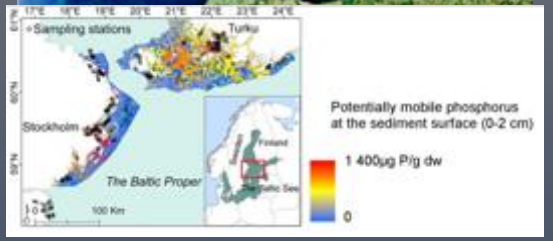
Lake Erie

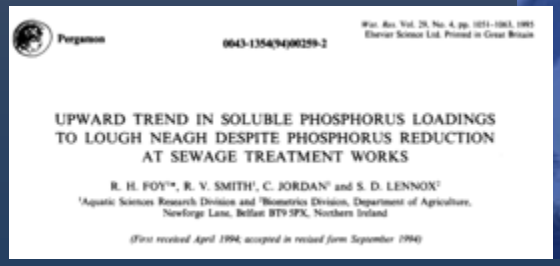


Chesapeake



Baltic Sea





Pergamon

0043-1354/94/00259-2

UPWARD TREND IN SOLUBLE PHOSPHORUS LOADINGS TO LOUGH NEAGH DESPITE PHOSPHORUS REDUCTION AT SEWAGE TREATMENT WORKS

R. H. FOY[1]*, R. V. SMITH[1], C. JORDAN[2] and S. D. LENNOX[2]

[1]Aquatic Sciences Research Division and [2]Biometrics Division, Department of Agriculture, Newforge Lane, Belfast BT9 5PX, Northern Ireland

(First received April 1994; accepted in revised form September 1994)

Eutrophication persists despite decades of watershed mitigation efforts

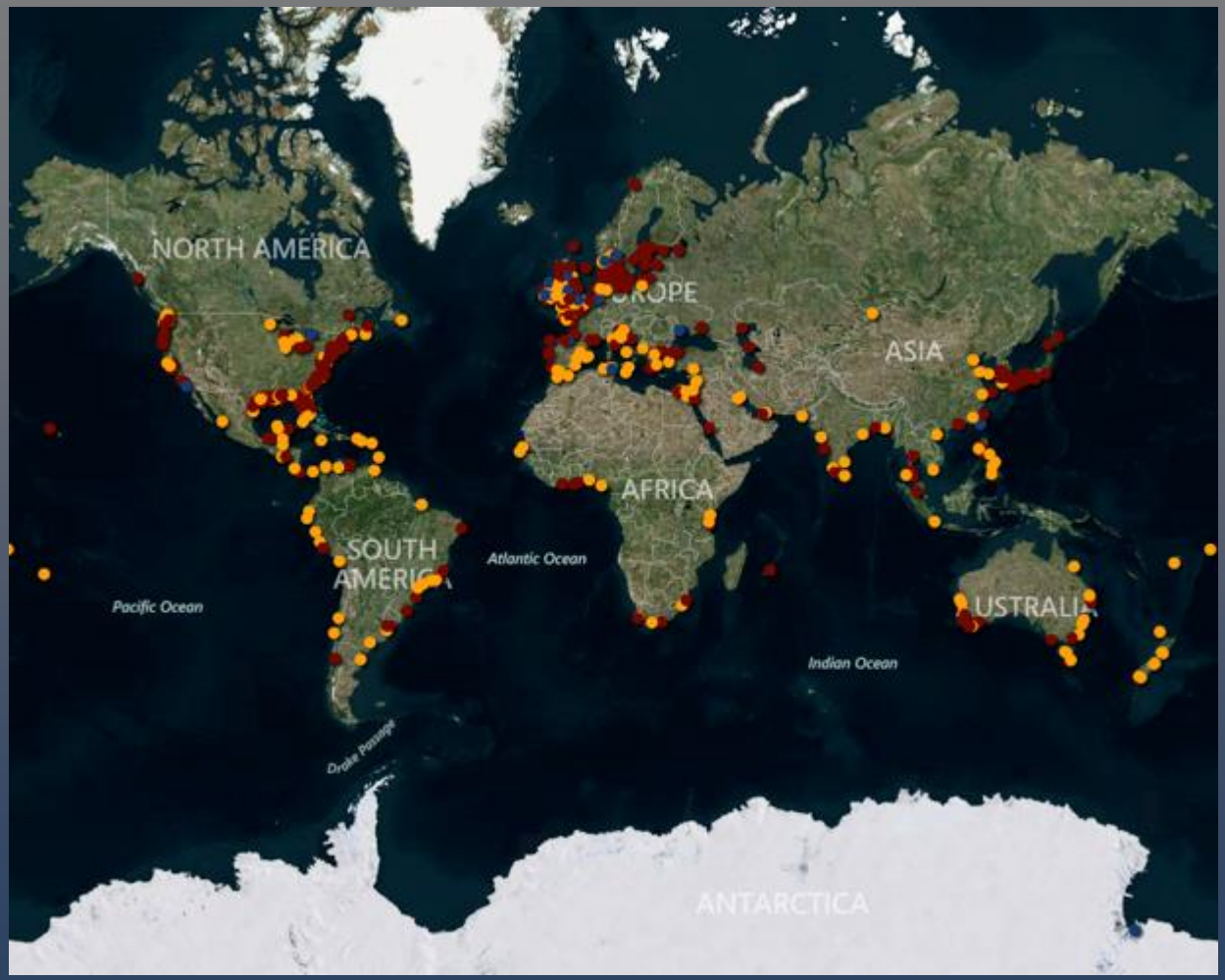


Image credit: World Resources Institute

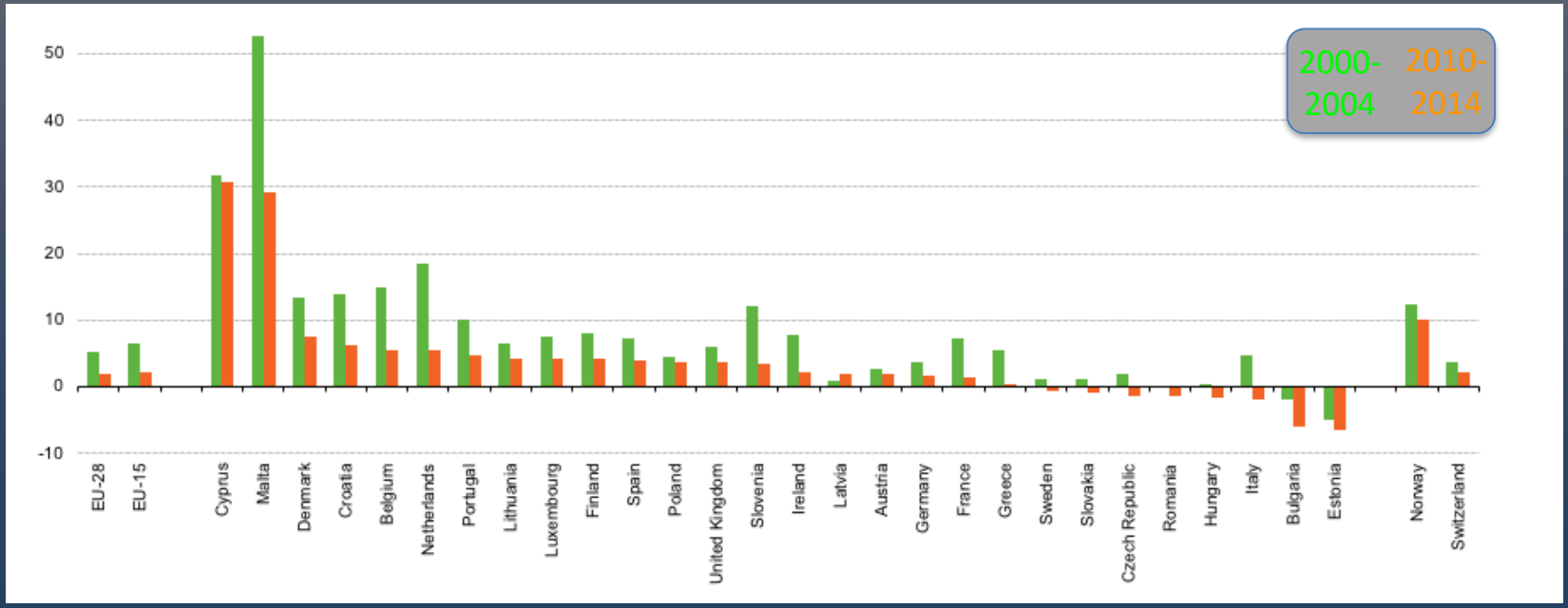


	Crop	Dairy	Swine
P imported (kg/ha)			
fertilizer	18	11	0
feed	0	30	104
P exported (kg/ha)			
milk/animals	0	12	20
crops	16	1	0
P balance (kg/ha)	2	29	84

Source: Lanyon (1999)

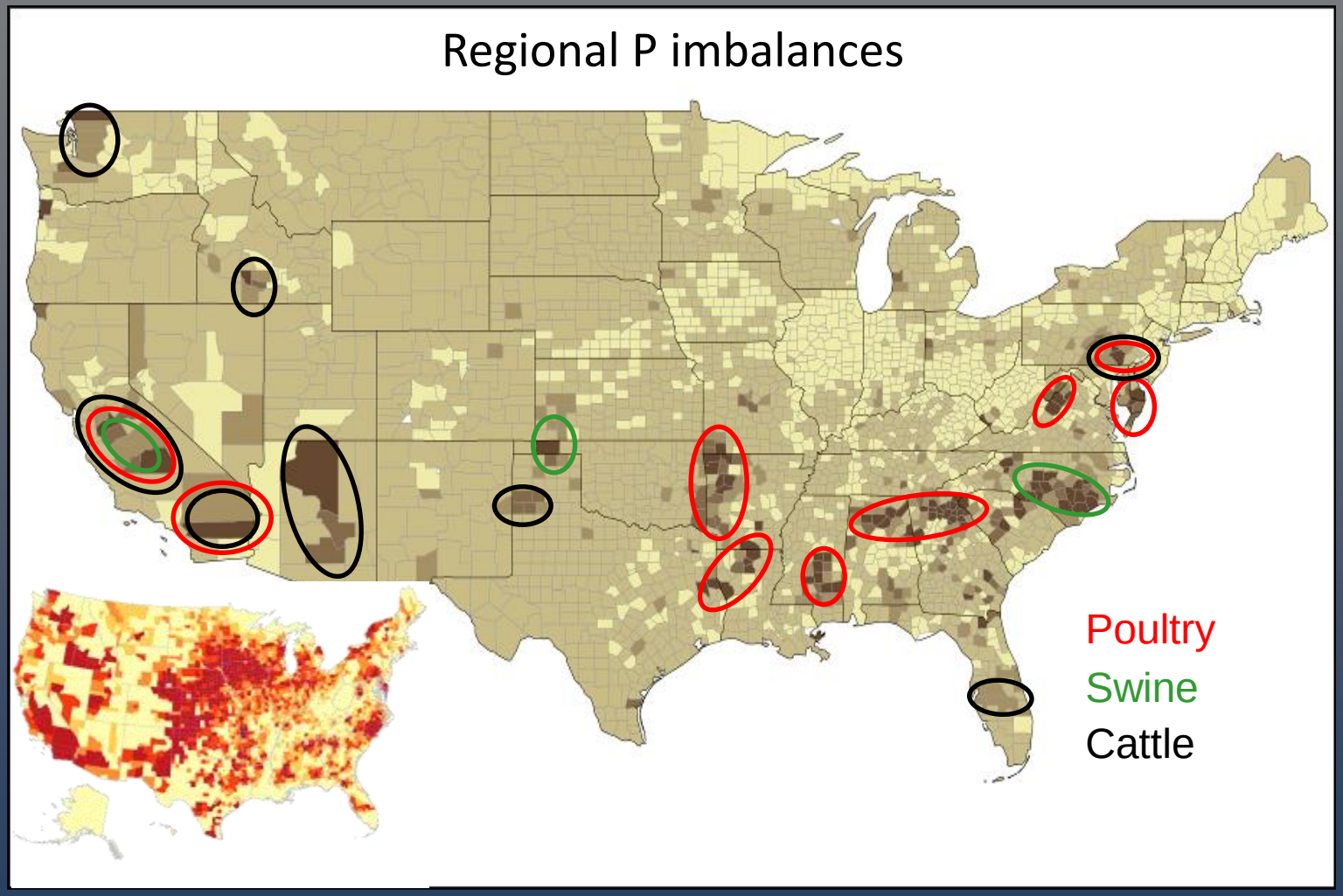
Thinking of P as a resource

a matter of budgets



“Legacy P” and animal agriculture

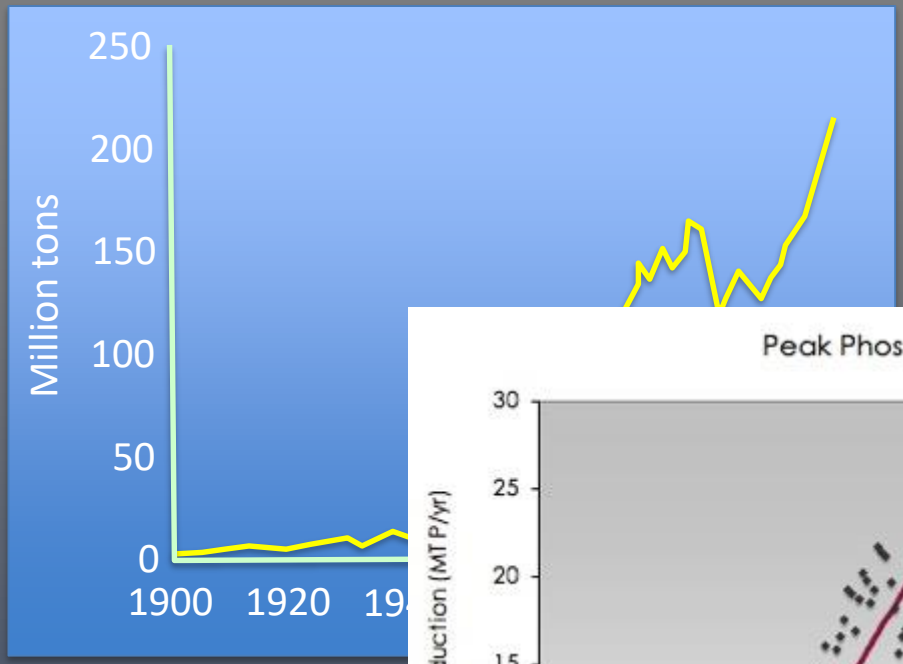
intensification and specialization of farming systems

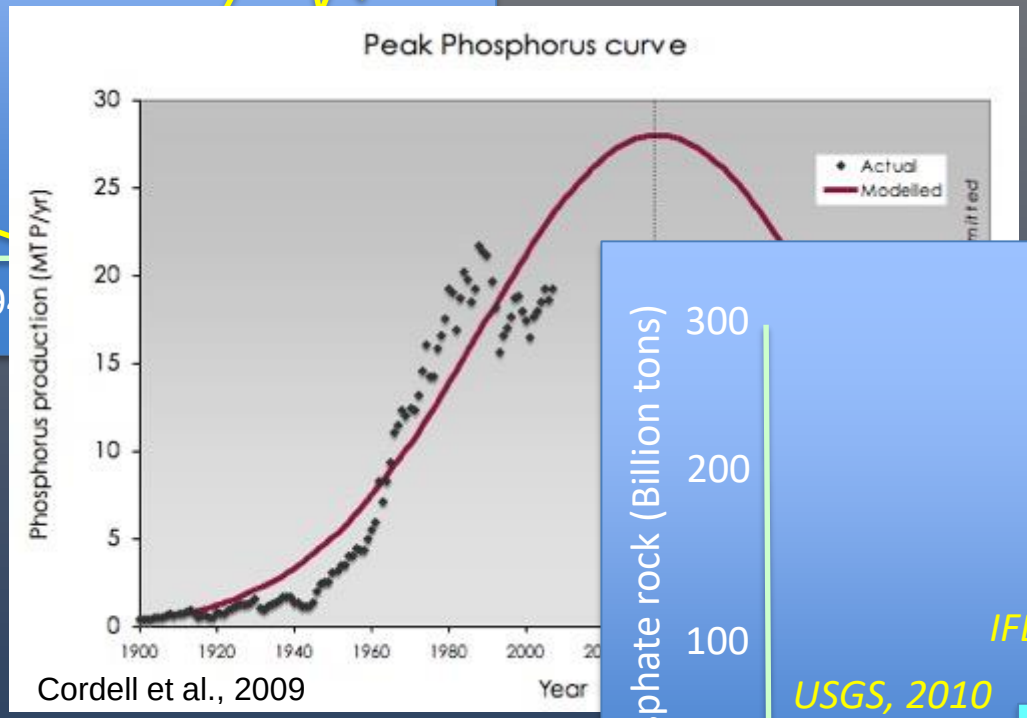


Maguire et al., 2007

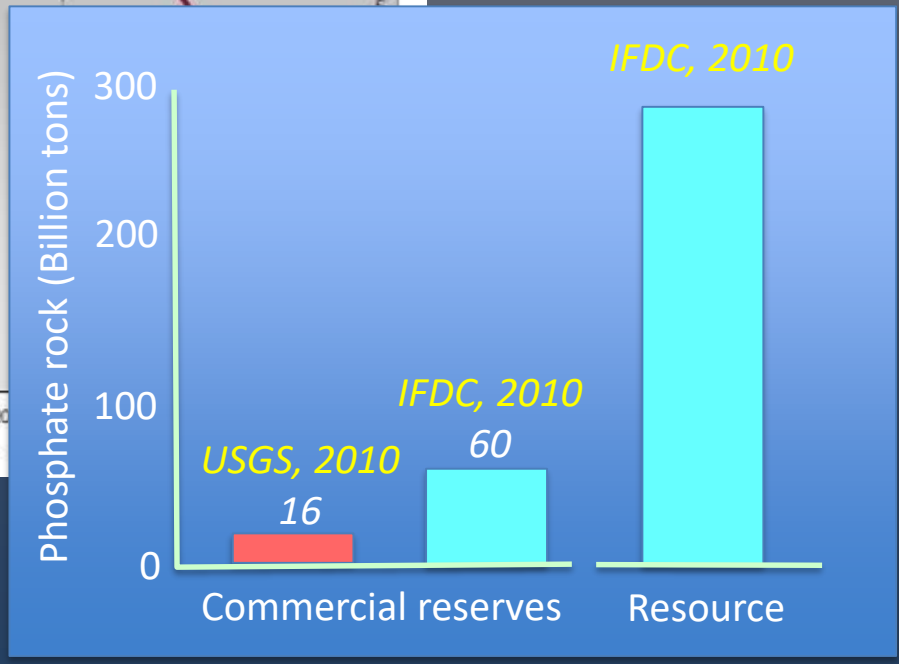
Phosphorus: circular economy poster child

Phosphorus: more valuable than oil?



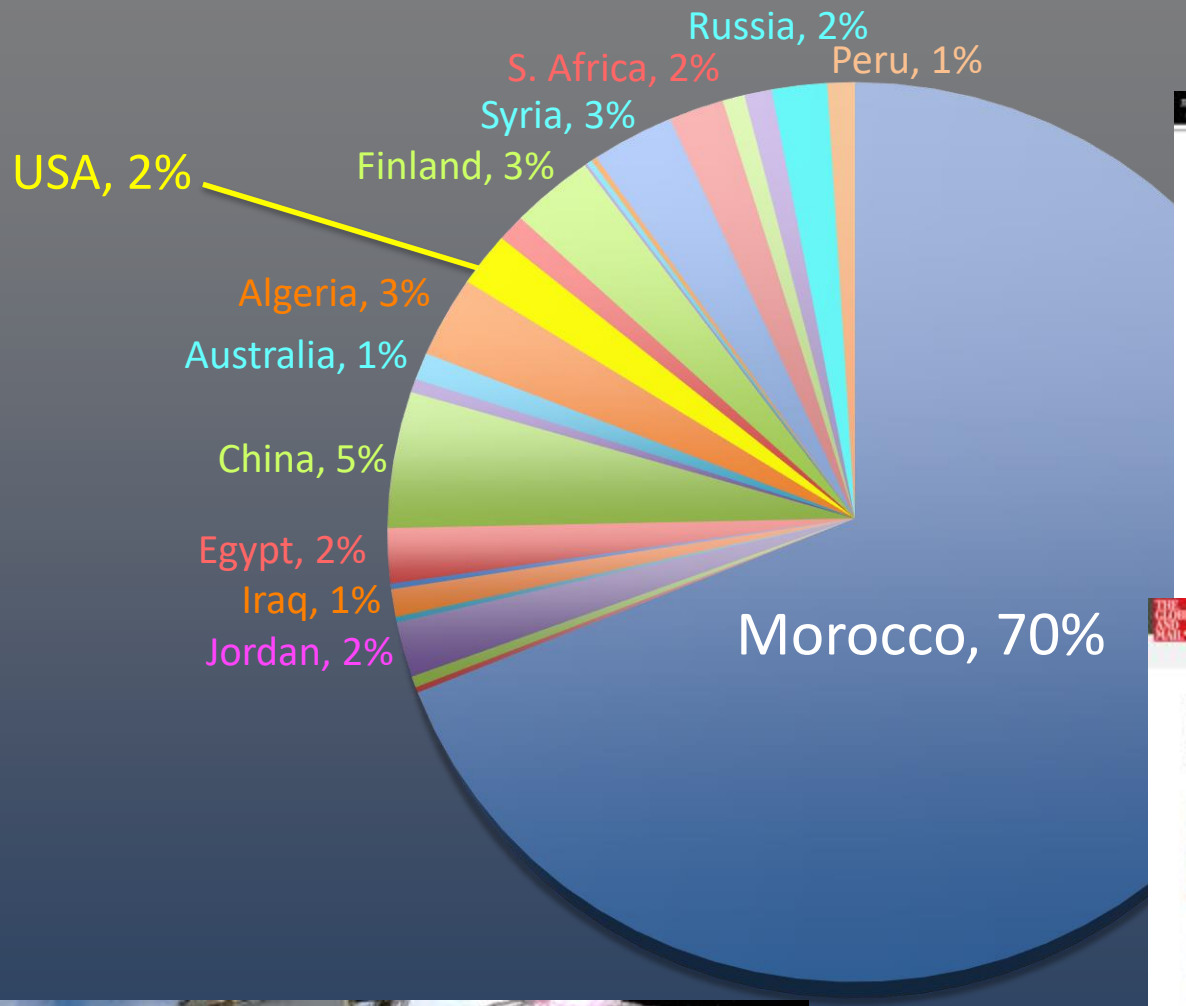


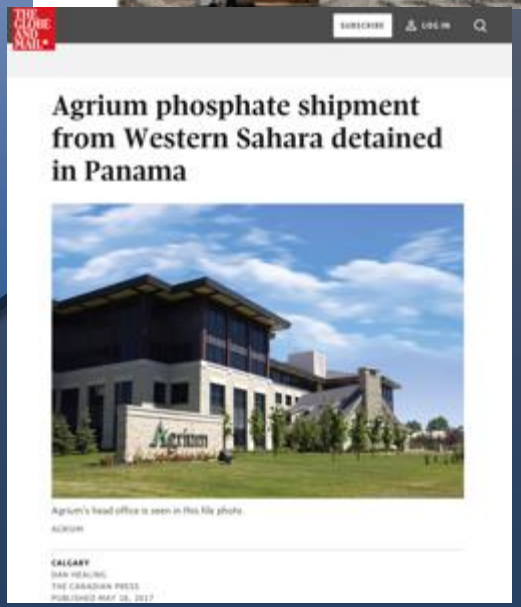
Cordell et al., 2009



Commercial reserves of rock phosphate – 2016

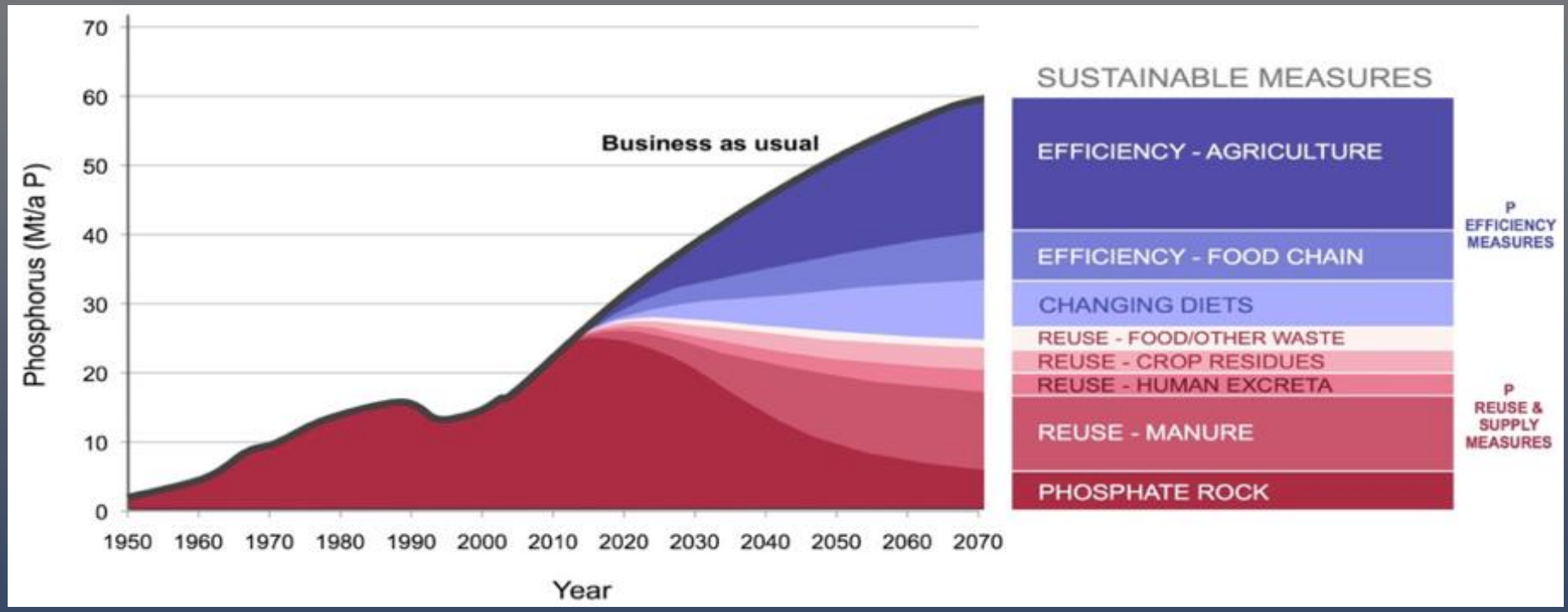
National case for food security





Opportunities for improvement

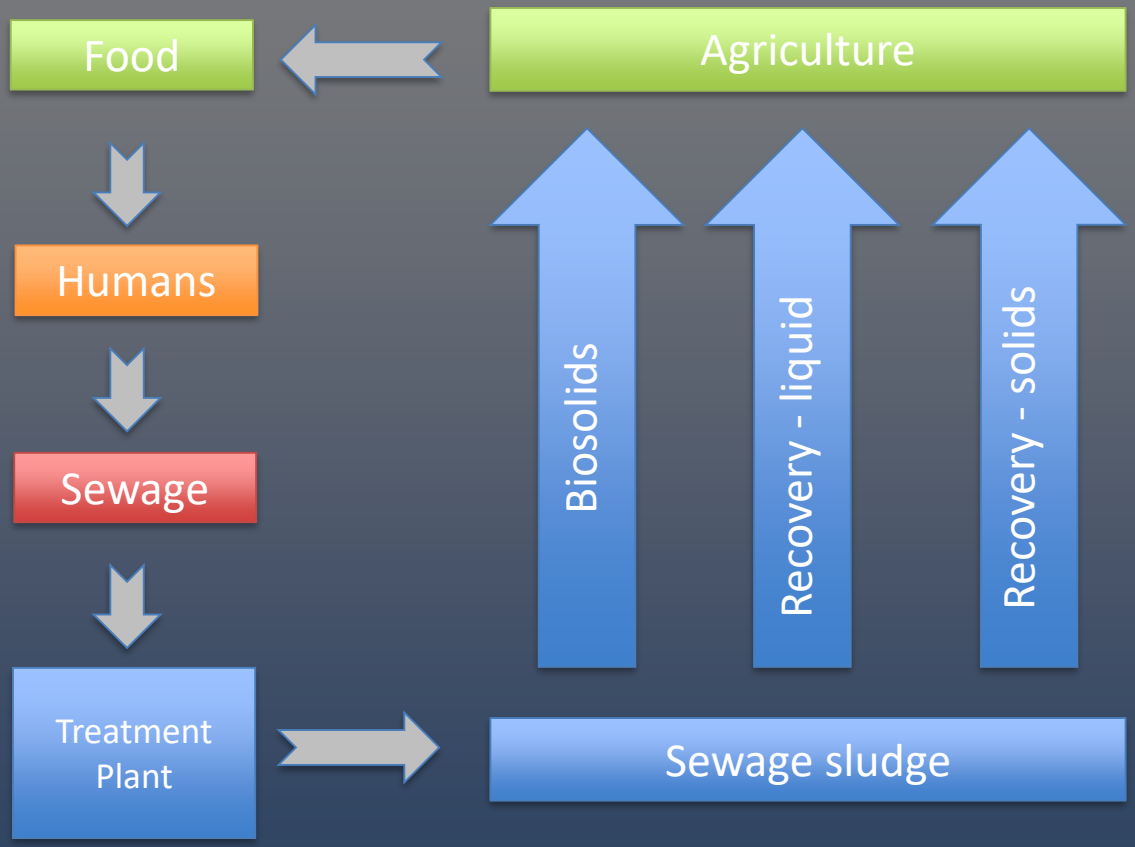
P Use Efficiency, Consumption, Recovery



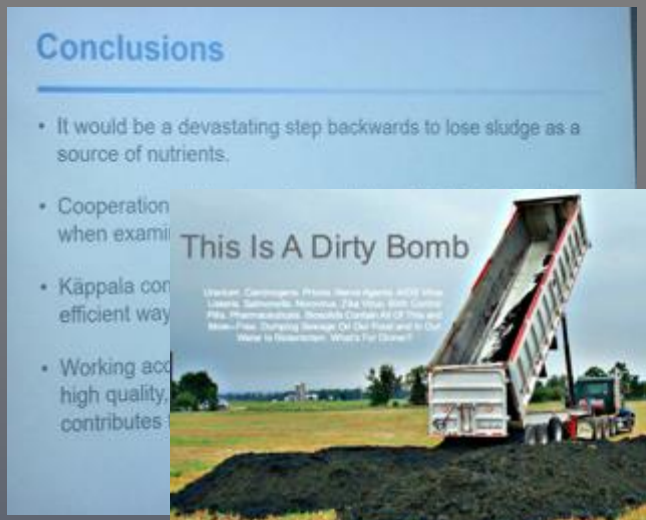
Source: Cordell, D.; White, S. Sustainable Phosphorus Measures: Strategies and Technologies for Achieving Phosphorus Security. Agronomy 2013, 3, 86-116. (Copied from https://phosphorusalliance.org/about/)

RECOVERY

a wastewater centric perspective



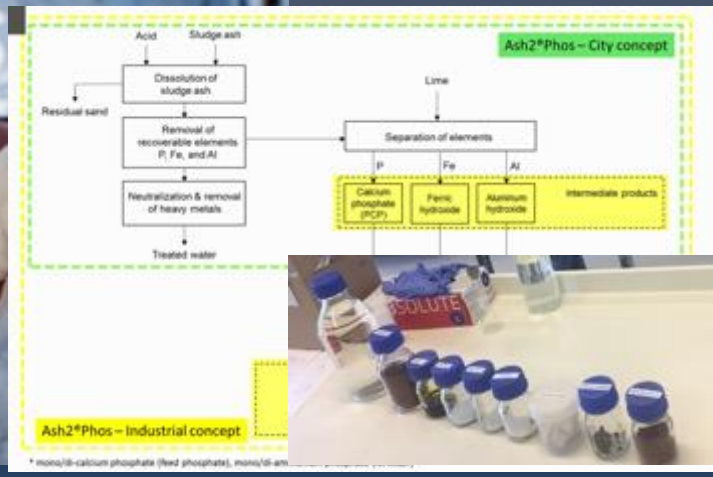
Biosolids Land Application
Increasingly Challenged



Struvite Recovery

HSY – New Research

Ash2Phos



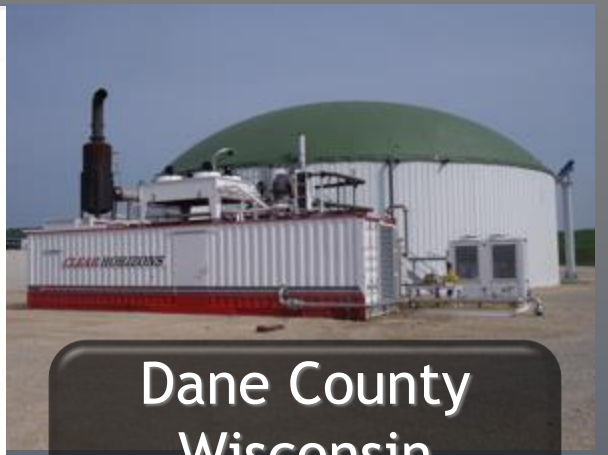
Nutrient recovery systems for CAFOs

Implementation challenges

Policies, markets, scale, incentives

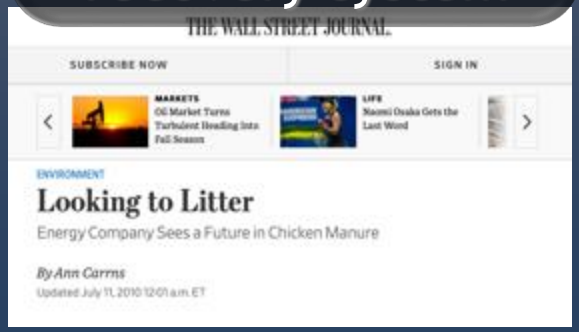
Purdue litter pelletizing plant

Valio
5500 Finnish Dairies
N and P
recovery system



Dane County Wisconsin manure digester

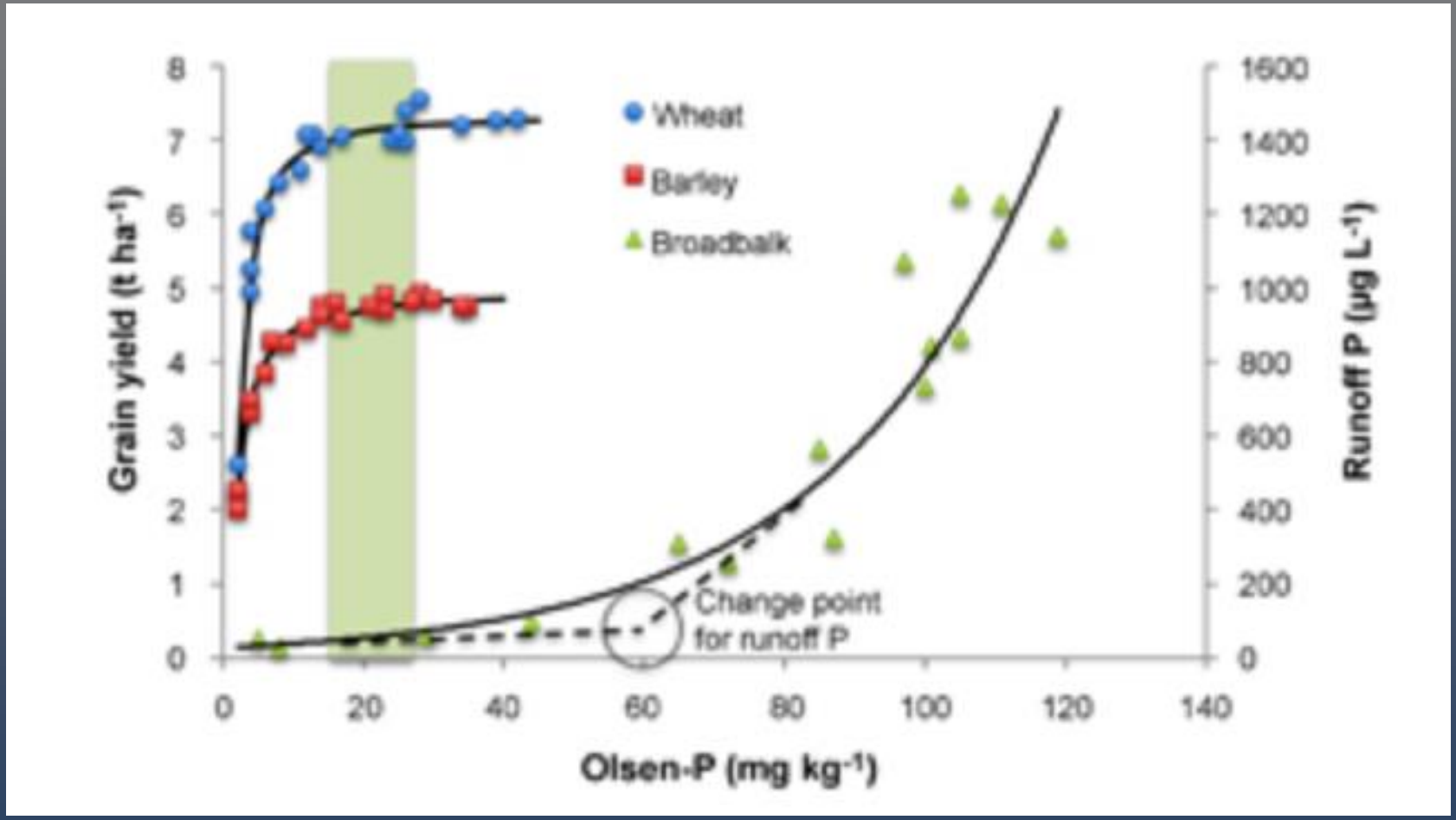
Fibrominn turkey litter power plant



Arkansas poultry litter baling

Food production and environmental health

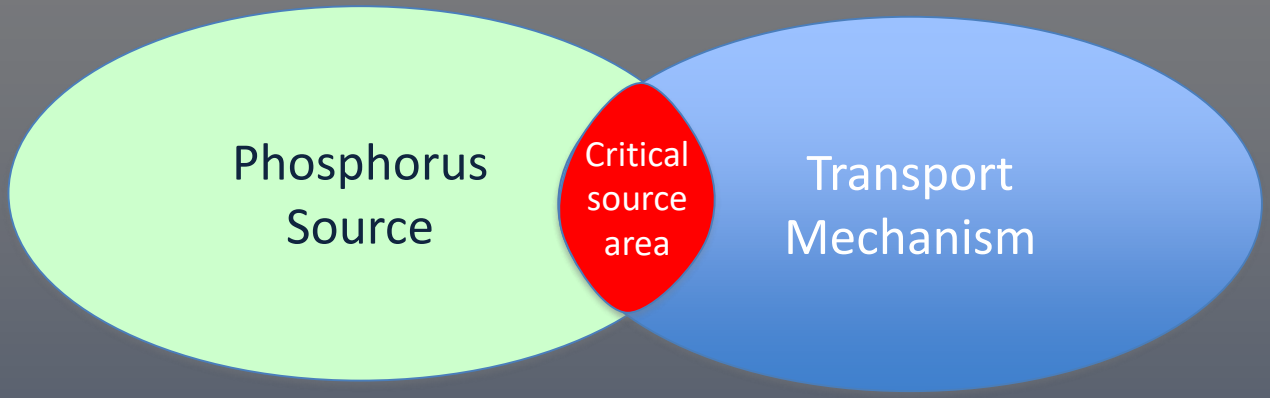
Moving beyond win-win assumptions



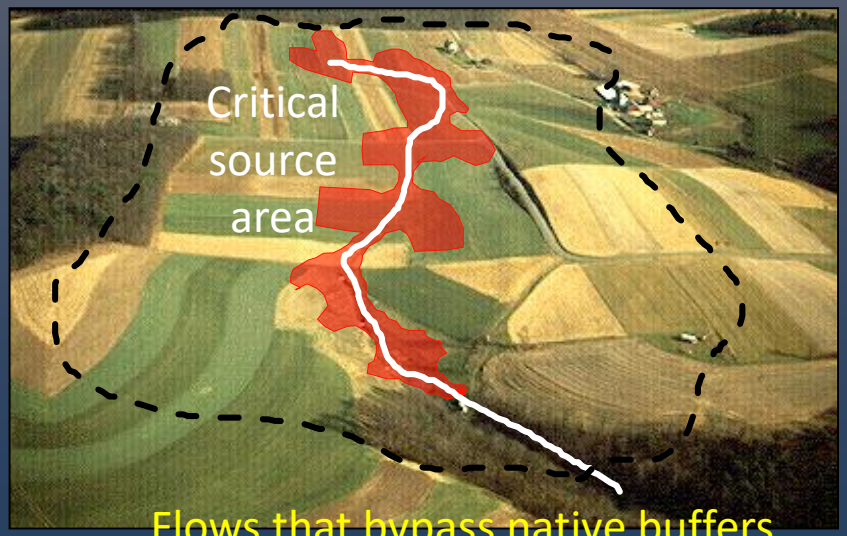
Obtained from Withers et al., 2017, displaying relationships of Poulton et al. (2013) and Heckrath et al. (1998)

Critical Source Area Management

Managing sources and transport pathways

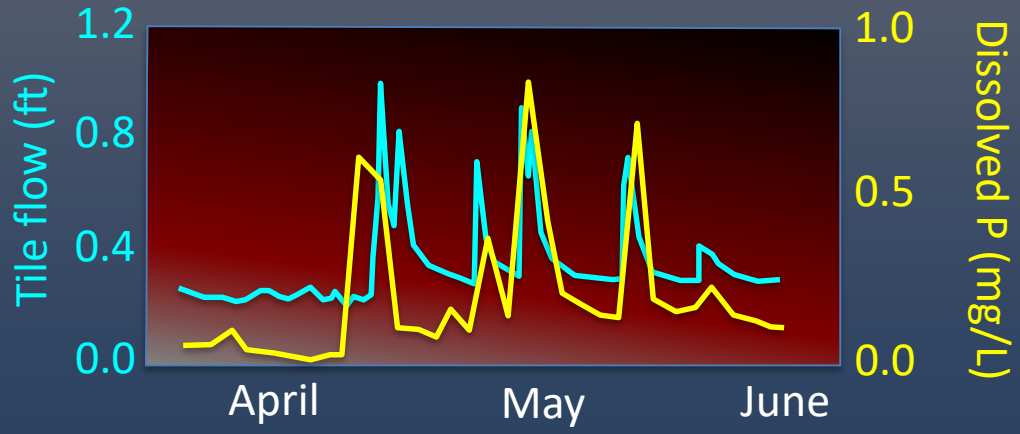


HOT SPOTS



Flows that bypass native buffers

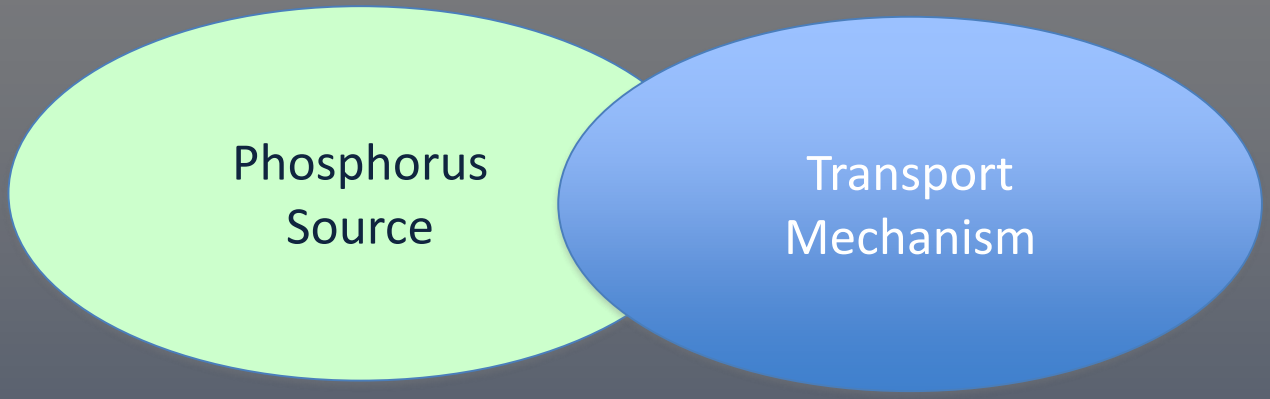
HOT MOMENTS



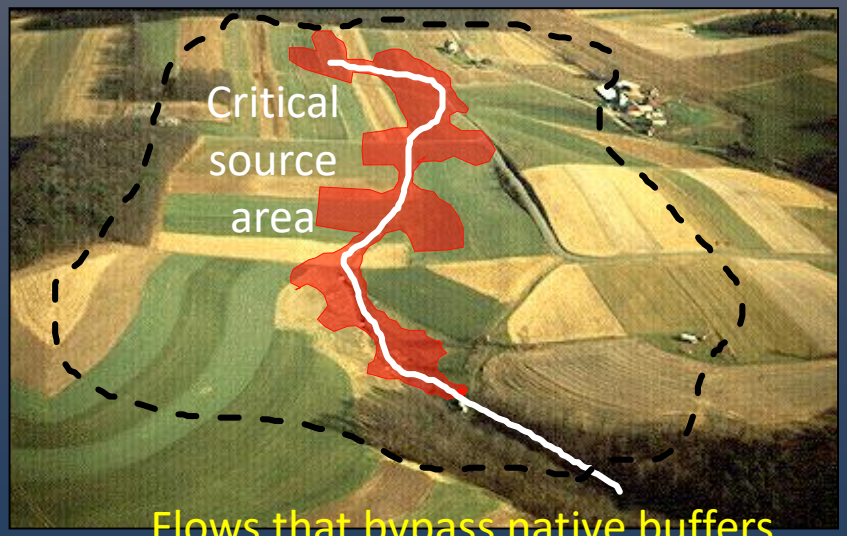
Source: King, USDA-ARS

Critical Source Area Management

Disconnecting sources and transport pathways

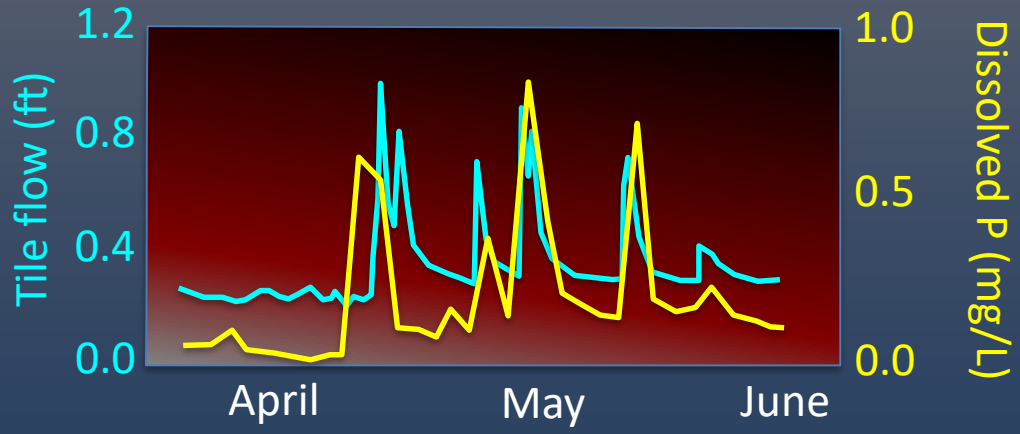


HOT SPOTS



Flows that bypass native buffers

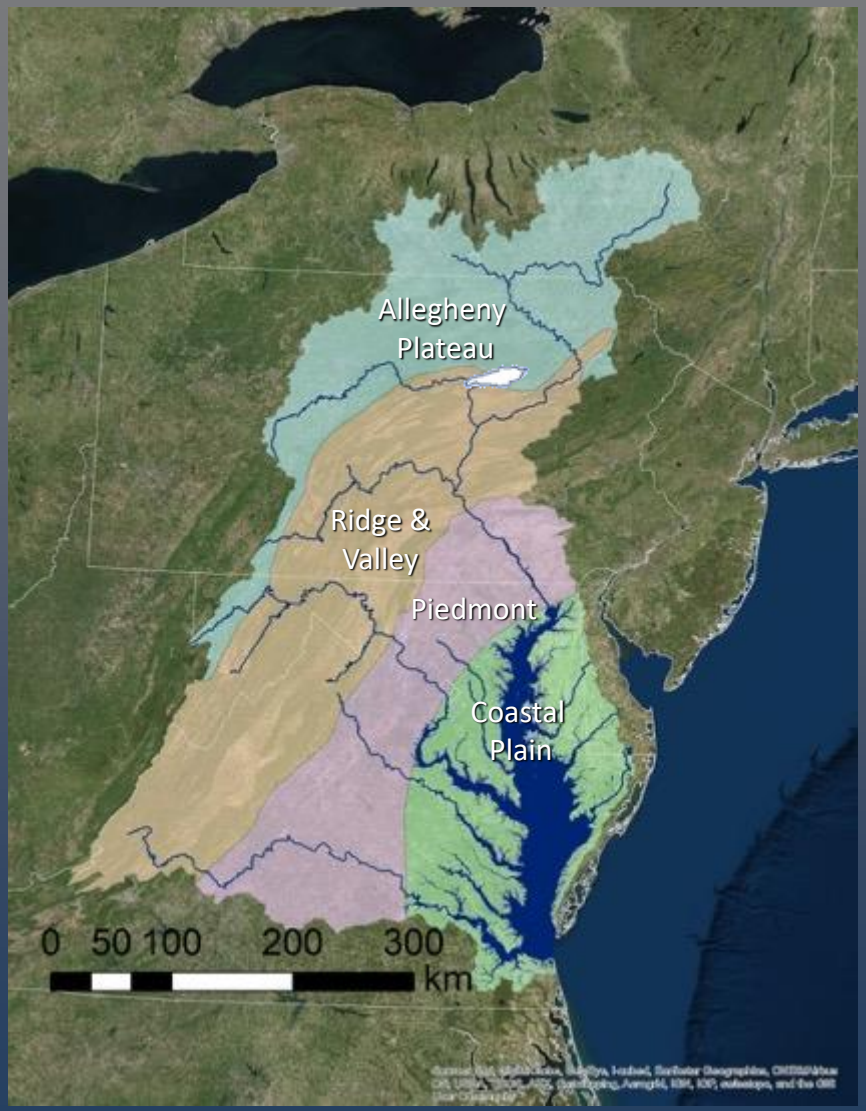
HOT MOMENTS

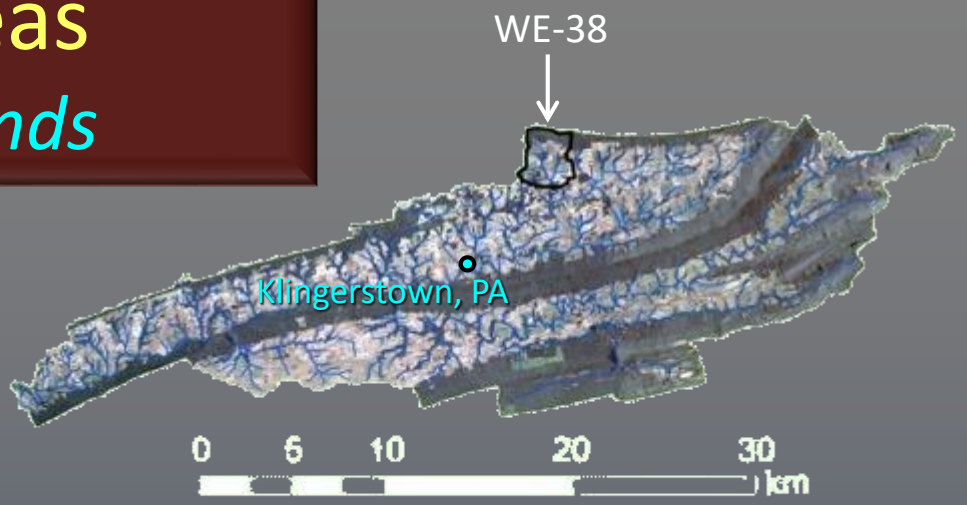


Source: King, USDA-ARS

Critical source areas

Chesapeake Bay uplands



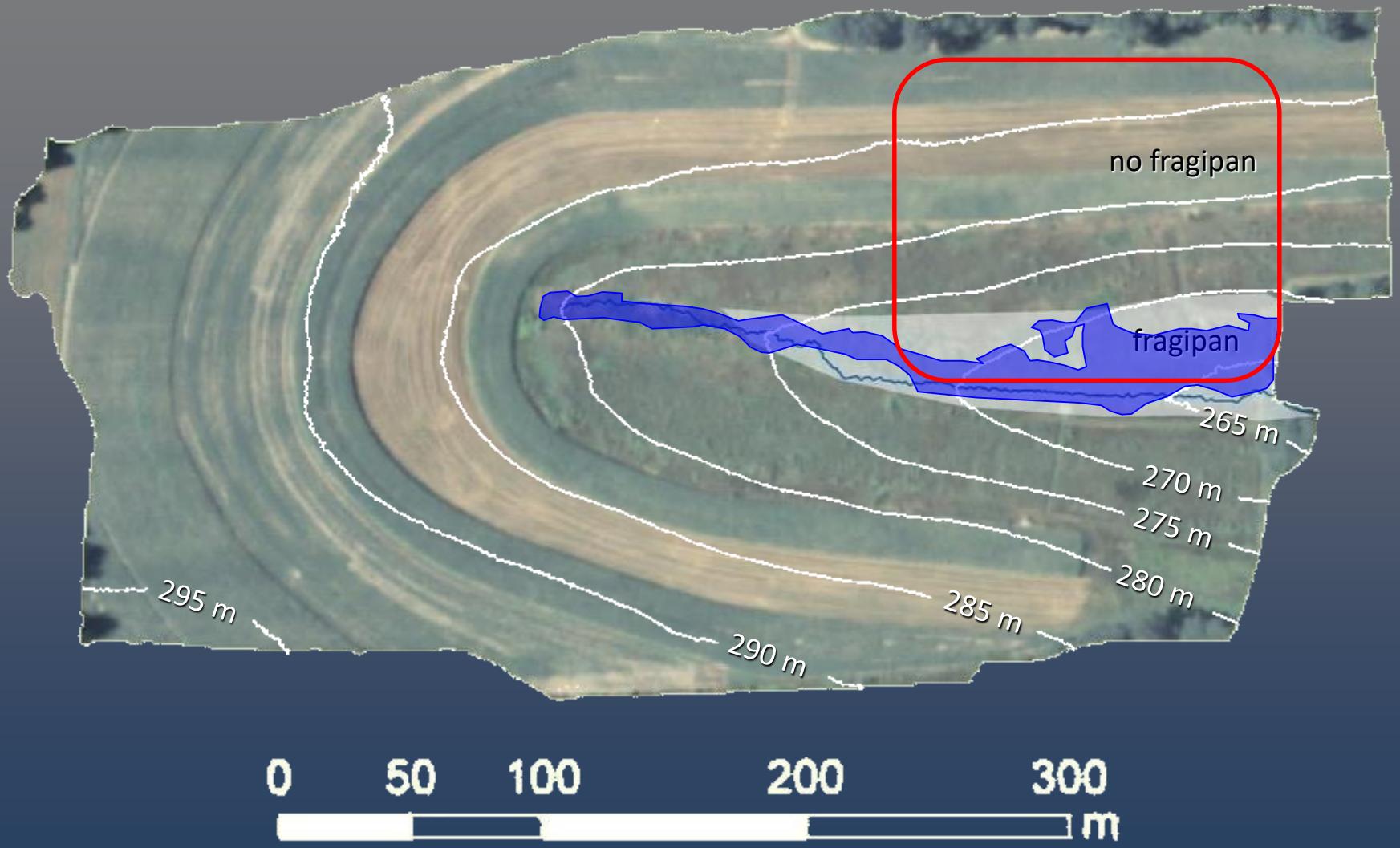


WE-38 Watershed (7.3 km^2)

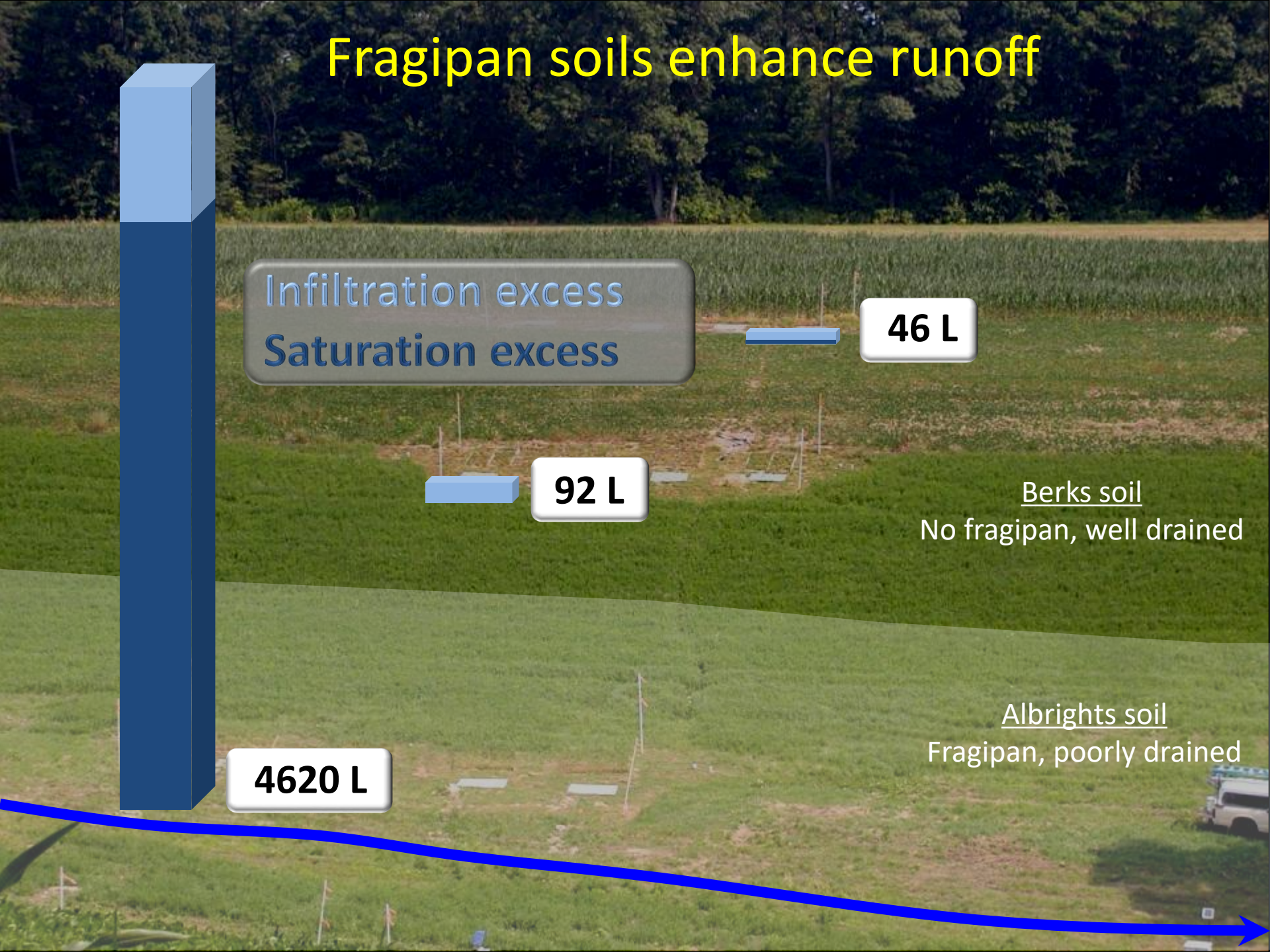
Mattern
(11 ha)

Fragipan soils and zones of saturation

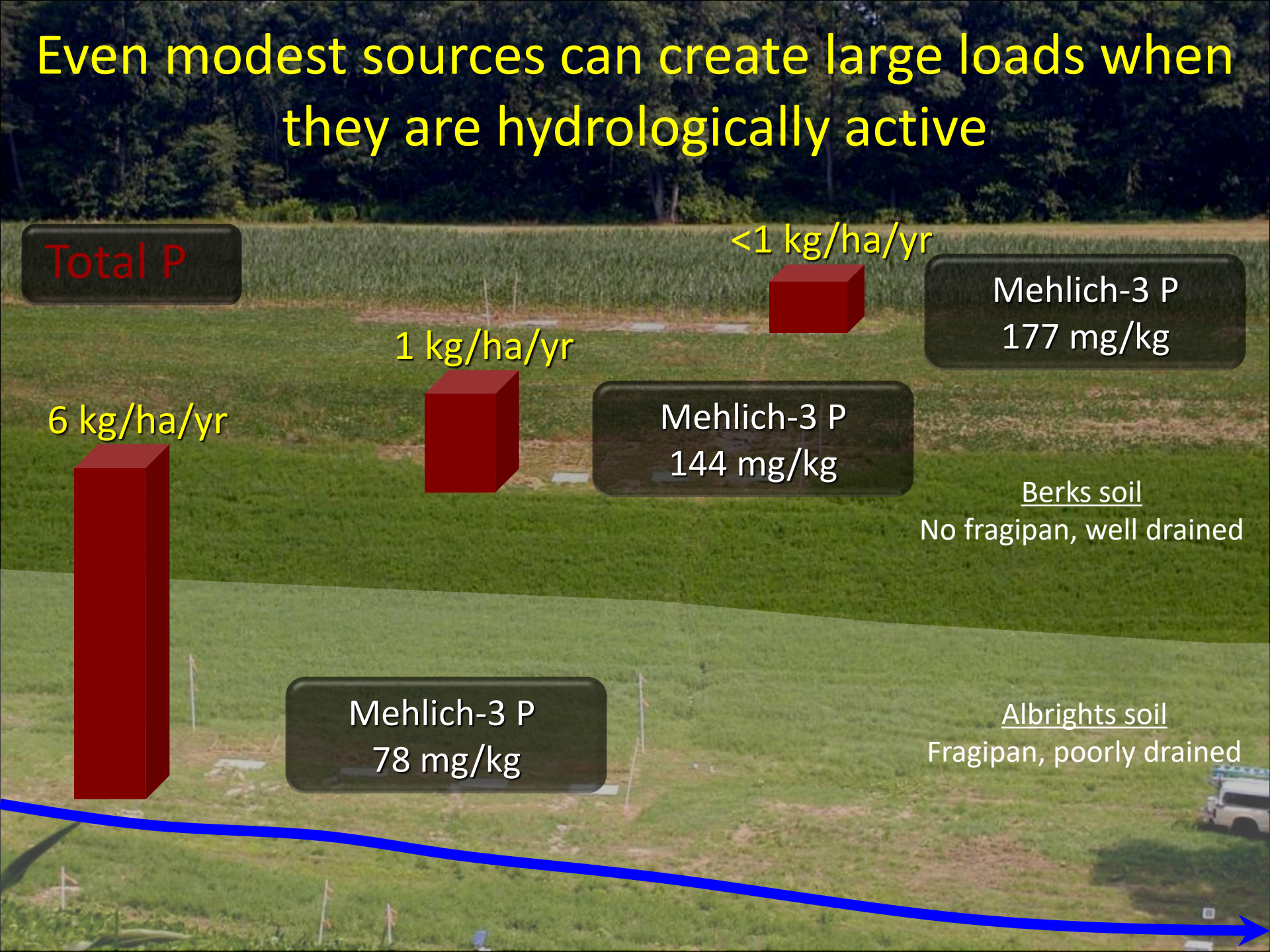
Late October 2003



Fragipan soils enhance runoff



Even modest sources can create large loads when they are hydrologically active



Field drainage – ditches and tiles

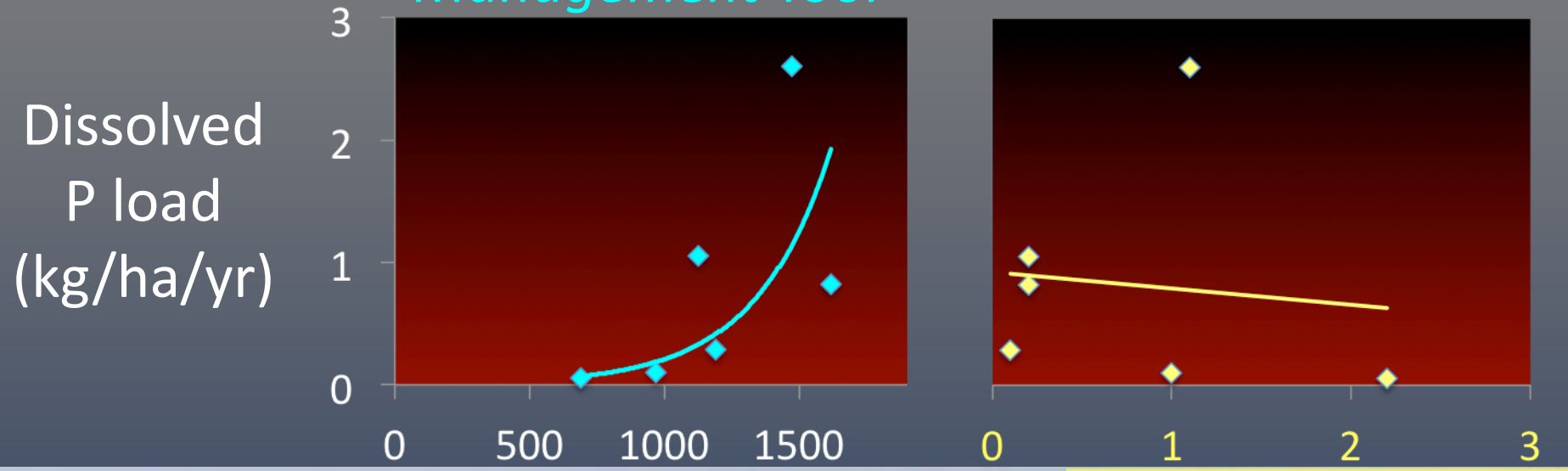
lower water tables, faster travel times, increased connectivity

Drainage in the P Index

Comparison with ditch P loadings

Maryland's P Management Tool

North Carolina's P Loss Assessment Tool



PMT Subsurface Score

PLAT's Subsurface Score

Shober et al., 2017. Univ. Delaware

BMPs for P

The allure of magic dust

structured liming and gypsum

Taylor & Francis Online

Acta Agriculturae Scandinavica, Section B — Soil & Plant Science

Volume 64, 2014 - Issue 5

230 3 1

ORIGINAL ARTICLES

Phosphorus leaching from clay soils can be counteracted by structure liming

Barbro Ulén & Ararso Etana

Download citation https://doi.org/10.1080/09064710.2014.920043

SUOMI SVENSKA SUPPORT US

Gypsum treatment of fields enhances water protection in agriculture

PRESS RELEASE

Gypsum treatment has been piloted as an innovative protection method under the NutriTrade project funded by the EU Interreg Central Baltic programme. The suitability of gypsum treatment for improving the state of the Archipelago Sea is being studied under the SAVE

Gypsum treatment of agricultural fields has proven to be a safe and effective method, approved by farmers, in reducing phosphorus load originating from agriculture to the Baltic Sea. The results are based on a large-scale pilot project testing the application of gypsum to agricultural fields in Southwest Finland. Large-scale use of gypsum would enable Finland to meet the goals set by the Baltic Marine Environment Protection Commission (HELCOM) for reducing the phosphorus load entering the Baltic Sea. Gypsum treatment would have extensive potential throughout the Baltic Sea area.

Reactors

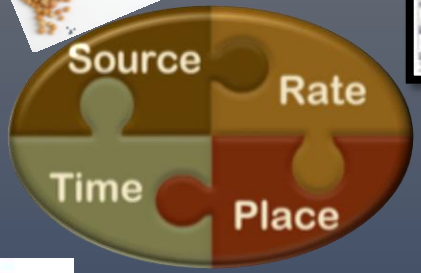
4R Nutrient Stewardship

A framework for strategic management

Analysis

Formulation

Soil testing



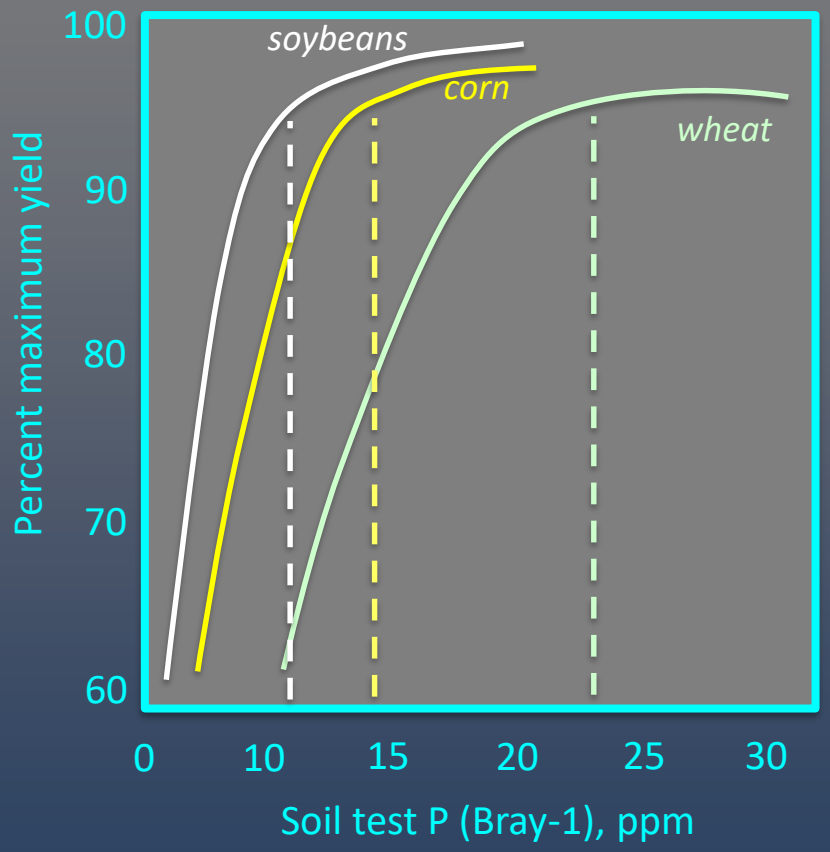
Field Assessment

To growing crops when risks are low

Delivery technologies

Soil fertility recommendations

Complex, old and opaque



Univ. Nebraska: *Coop. Ext. Publ., 1999*

North American Tests

Ammonium Lactate
Bray-Kurtz 1, Bray-Kurtz 2
Morgan's, Cornell Morgan's
Modified Morgan's
Mehlich-1
Mehlich-3
Kelowna, Modified Kelowna
Miller-Axley
Olsen
Saskatchewan

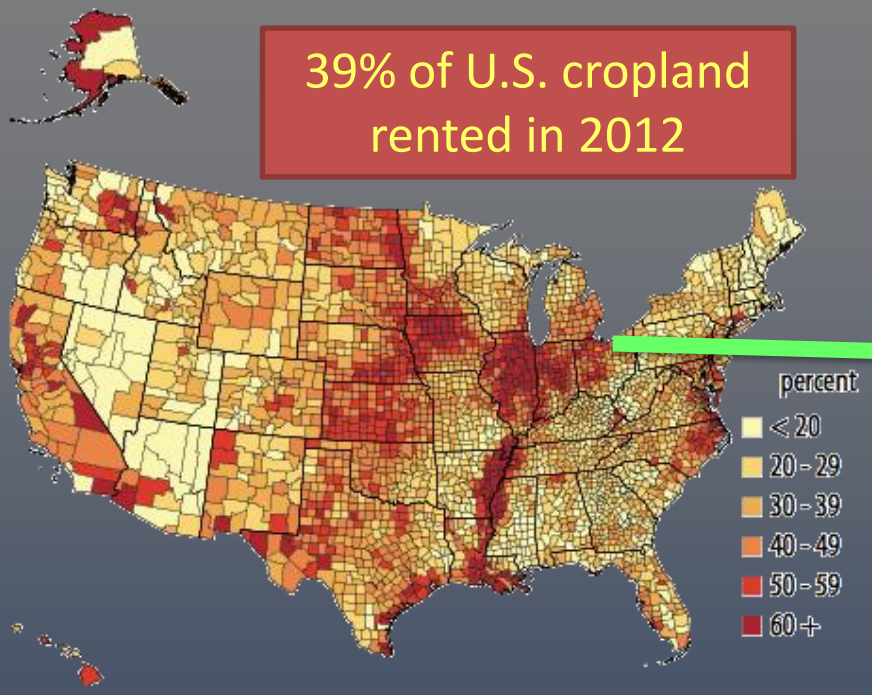
Proposed Tests

Fe-oxide strip
Resin
Haney soil health test?

Soil P maintenance and land rental

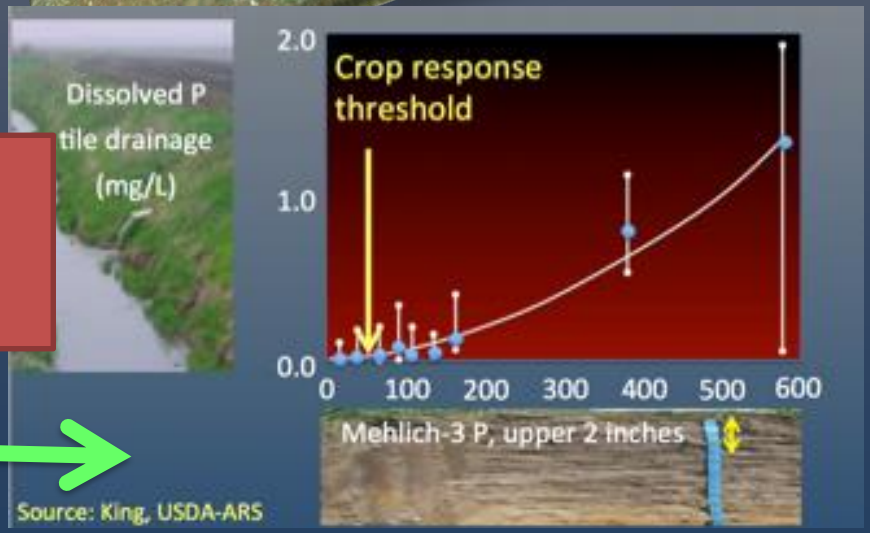
Contractual obligations

39% of U.S. cropland rented in 2012



More than 50% of cropland in Western Lake Erie is rented

Soil P maintenance required in rental agreement



Revisiting P fertilizer recommendations

How low can you go?

Early season signs of deficiency are not the same as yield decline

Corn

Grapes

Struvite – slow release fertilizer

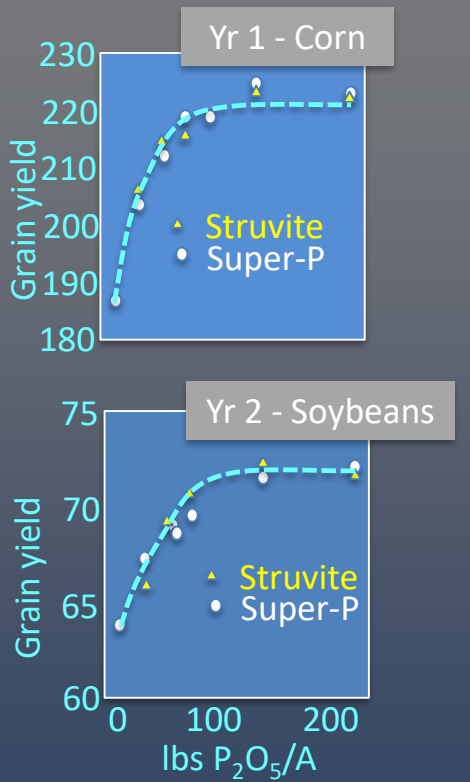
generally substitutes for high solubility fertilizers

Table 4. List of experiments reporting the fertilizer value of struvite

Citation	Year	Type	Crop	Struvite Source	Improvement in crop*		
(Bridger et al.)	1962	pot	Herbaceous flowers, tomatoes	USA, chemical reagents	0-100	NR	SOL
(Bridger et al.)	1962	field	Shrubs, grasses	USA, chemical reagents	40-75	NR	
(Terman & Taylor)	1965	pot	Maize	USA, chemical reagents	40	SS	
(Ghosh *et al.*)	1996	pot	Chickpea, gram	India, chemical reagents	50	SS	SOL
(Goto)	1998	pot	Komatsuna, green vegetable	Japan, "recovered" struvite	50	SS	SOL
(Johnston & Richards)	2003	pot	Ryegrass	UK, chemical reagents	100	SS	SOL
(Johnston & Richards)	2003	pot	Ryegrass	Japanese sewage, and Dutch sewage & manure	100	SS	SOL
(Johnston & Richards)	2003	pot	Ryegrass	Spanish red dye liquor, US corn liquor	100	SS	SOL
(Li & Zhao)	2003	pot	Cabbage, chard, spinach, etc	Hong Kong, landfill leachate	>100	SS	
(Romer)	2006	pot	Ryegrass	German and USA manure	>100	SS	SOL
(Romer)	2006	pot	Ryegrass	German, Italian, and Japanese sewage	>100	SS	SOL
(Gonzalez Ponce & Lopez-de-Sa)	2007	pot	Perennial ryegrass	Spain, municipal wastewater		SS	>SOL
(Montag *et al.*)	2007	pot	unspecified	Germany, sewage sludge		NR	SOL
(Plaza et al.)	2007	pot	Ryegrass	Spain, municipal wastewater	>100	SS	SOL
(Ganrot *et al.*)	2007	pot	Wheat	Sweden, human urine, also included zeolites	30-100	SS	
(Ponce & Lopez-de-Sa)	2008	pot	White lupine	Spain, municipal wastewater		NR	SOL
(Cabeza Perez et al.)	2009	pot	Maize	Germany, sewage sludge	25-100	SS	SOL
(Cabeza Perez et al.)	2009	field	Rapeseed and winter barley	Germany, sewage sludge	0-40	NS	SOL
(DLV)	2009	field	Flowers, potatoes, Brussels sprouts	Netherlands, potato wastewater		NR	
(Massey et al.)	2009	pot	Spring wheat	USA, dairy waste and process wastewater	<25	SS	<SOL
(Gonzalez Ponce *et al.*)	2009	pot	Lettuce	Spain, municipal wastewater		SS	SOL
(Weinfurtner et al.)	2009	pot	Maize	Germany, sewage sludge	20-100	SS	SOL
(Yetilmezsoy & Sapci-Zengin)	2009	pot	Purslane, cress, grass	Turkey, digested poultry manure	>100	NR	
(This study)	2010	field	Maize	Netherlands, urine and black water	<30	NS	SOL

* Number refers to % improvement over control in P-uptake and/or yield; SS = improvement is statistically significant; NS = improvement is not statistically significant; NR = statistics not reported; SOL = comparable to soluble fertilizer.

Adapted from Gell et al., 2010



Adapted from Thompson et al., 2013. Iowa State Univ.

Better Fertilizer Decisions for Cropping Systems

Australia's model program

Laboratories
Consultants

Better Fertilizer Decisions for Cropping Systems

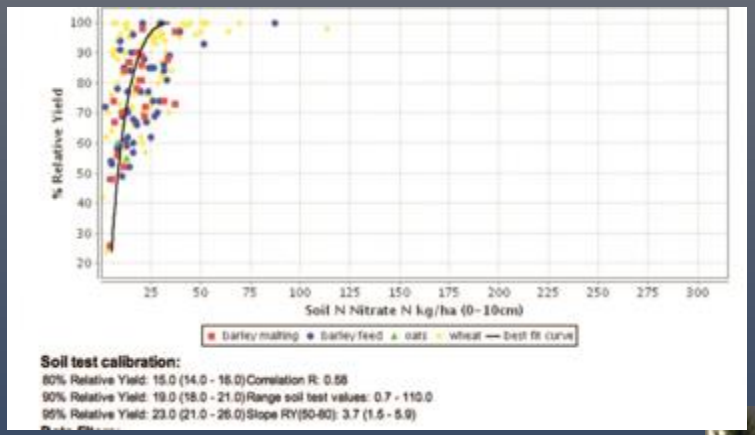
Australia's model program

BFDC Database

5000 soil test/crop response relationships

1960s to present

Standardized (depth, response units, etc)



Calibration

BFDC Interrogator program

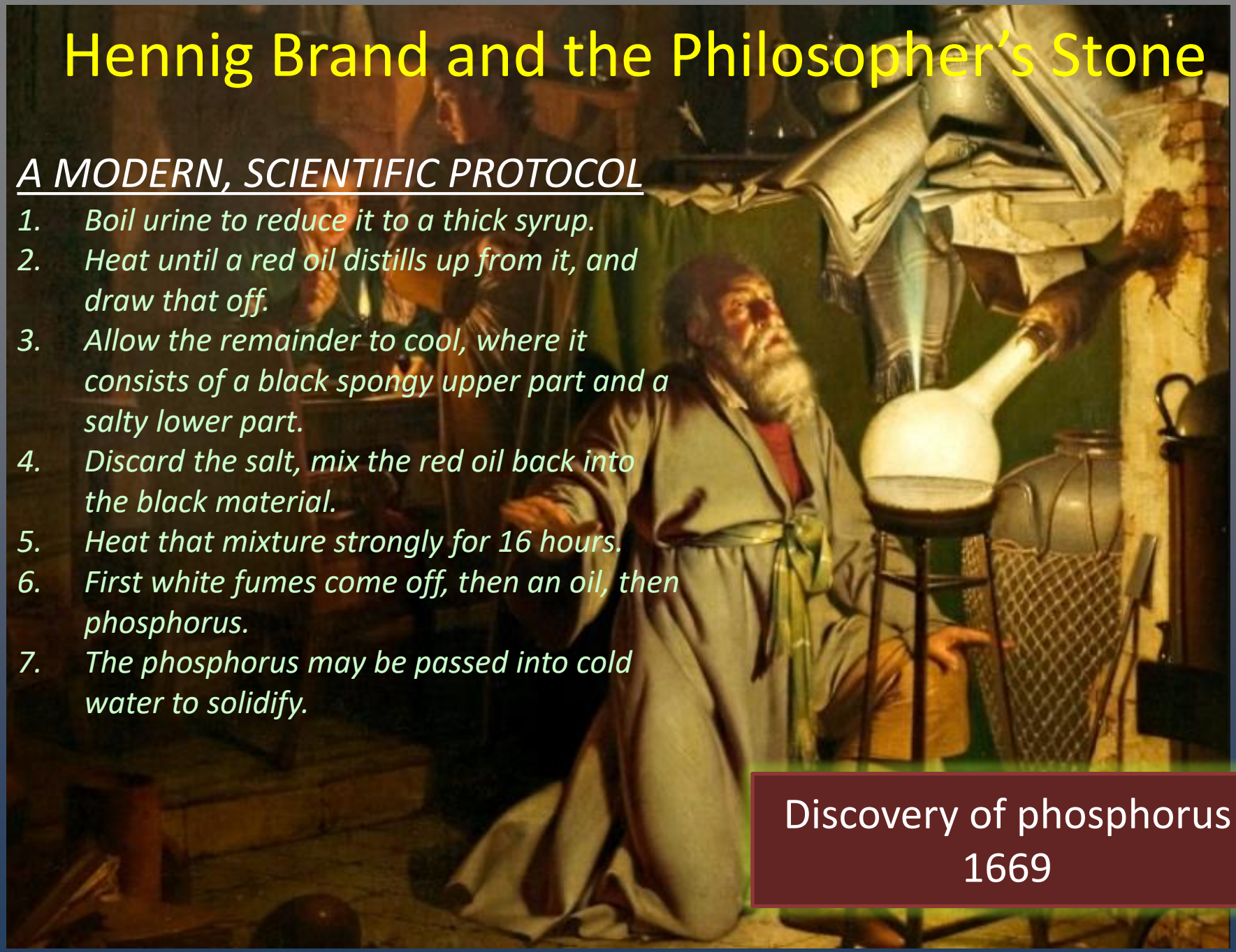
Transparency

Consistency

Certification

Training

Hennig Brand and the Philosopher's Stone



A MODERN, SCIENTIFIC PROTOCOL

1. *Boil urine to reduce it to a thick syrup.*
2. *Heat until a red oil distills up from it, and draw that off.*
3. *Allow the remainder to cool, where it consists of a black spongy upper part and a salty lower part.*
4. *Discard the salt, mix the red oil back into the black material.*
5. *Heat that mixture strongly for 16 hours.*
6. *First white fumes come off, then an oil, then phosphorus.*
7. *The phosphorus may be passed into cold water to solidify.*

Discovery of phosphorus
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