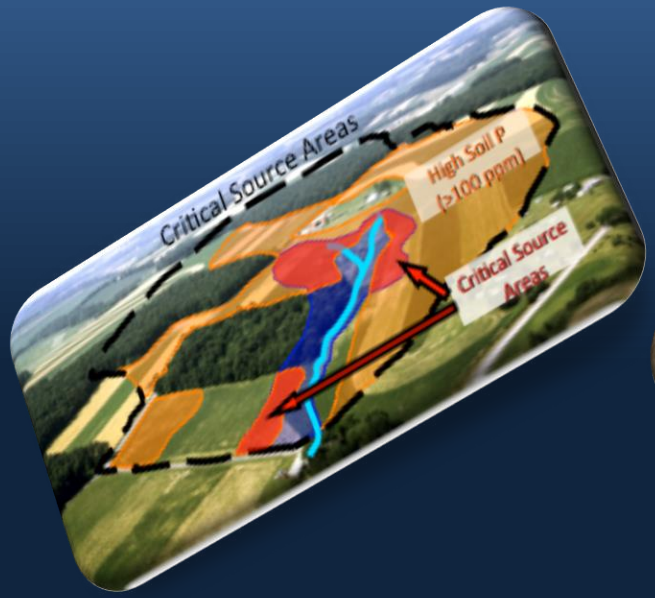
Phosphorus loss in runoff

Understanding the trade-offs of management



Pete Kleinman, Doug Smith and Tony Buda

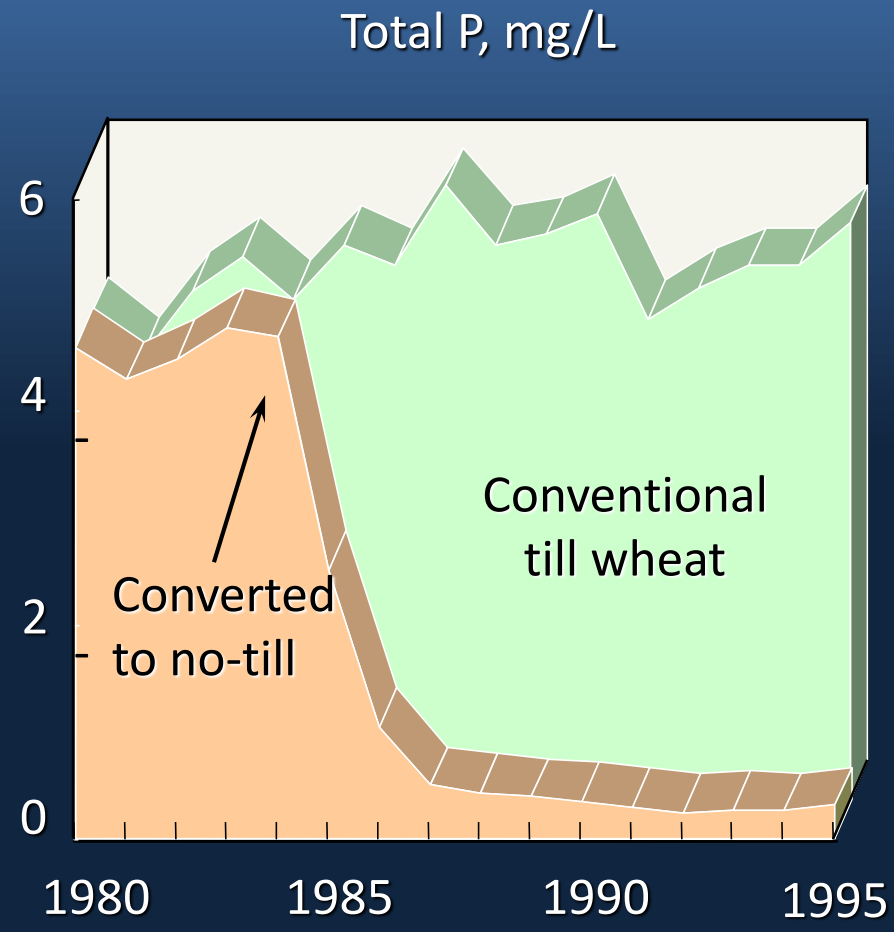
USDA Agricultural Research Service

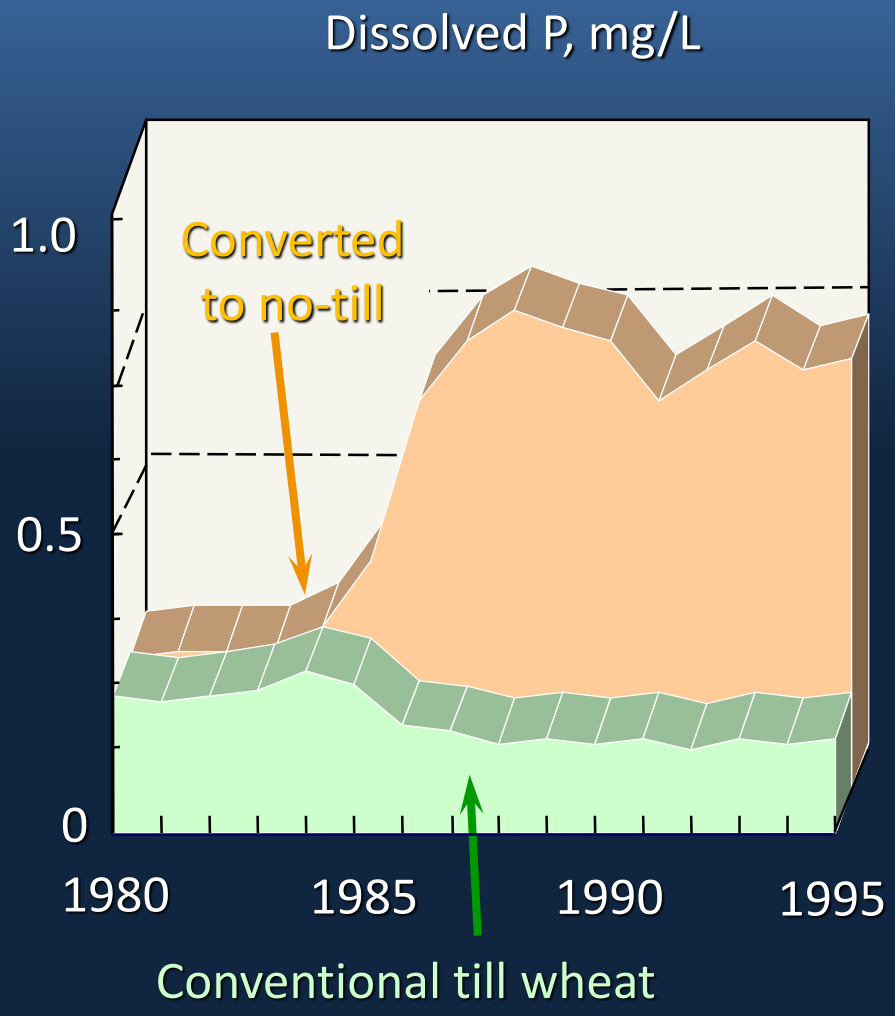
State College, PA and Temple, TX

Unintended Outcomes

Conservation paradox

No-till reduced erosion by 95%





Sharpley & Smith, 1994 – El Reno, OK

What happened?

The conservation paradox for P

Vertical Stratification

Build up of soluble P sources on soil surface

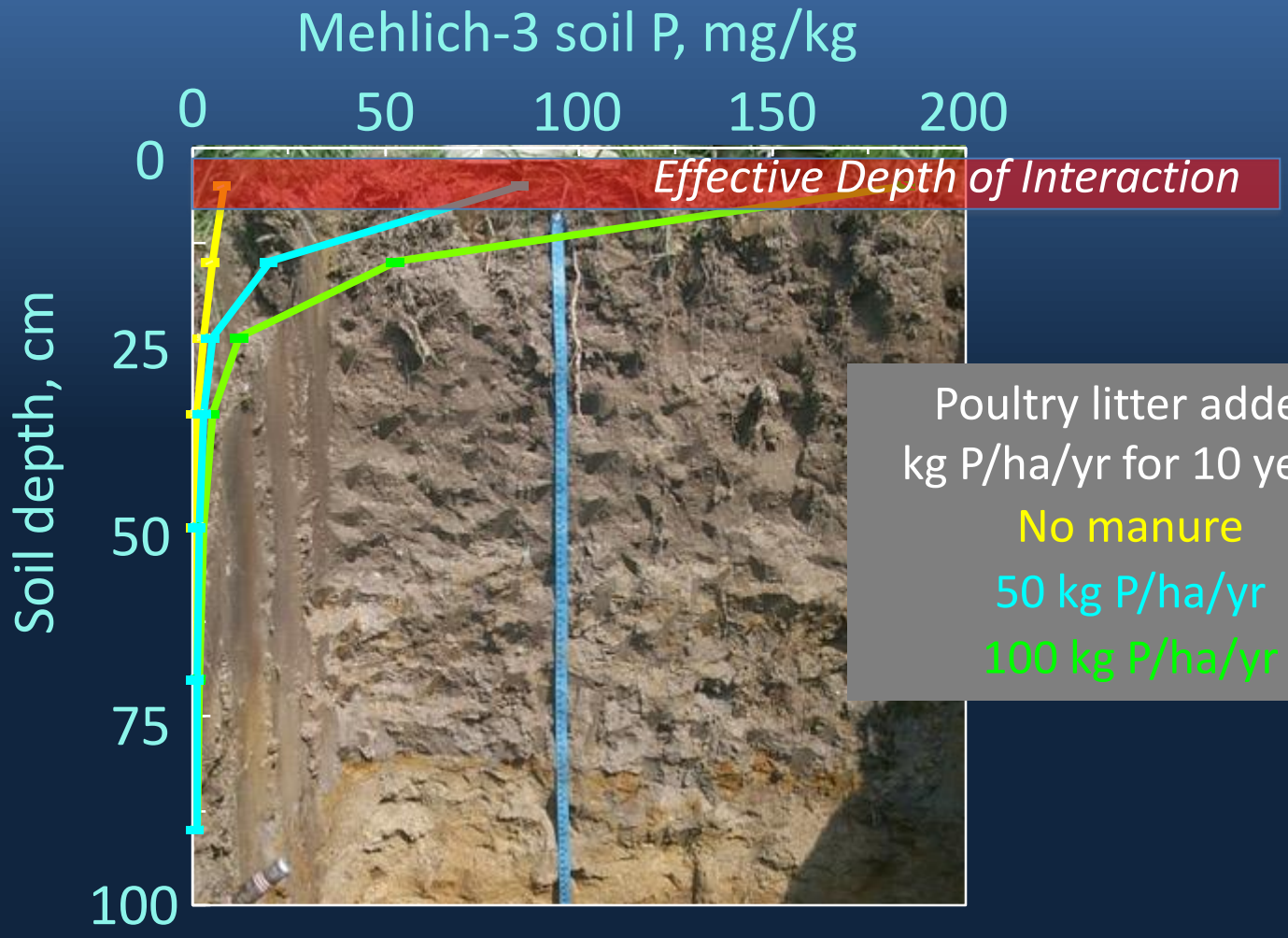
Dissolved P enrichment

As we control erosion, finer, more enriched sediment is selectively eroded

Vertical stratification

Vertical stratification of soil P

P accumulates near surface

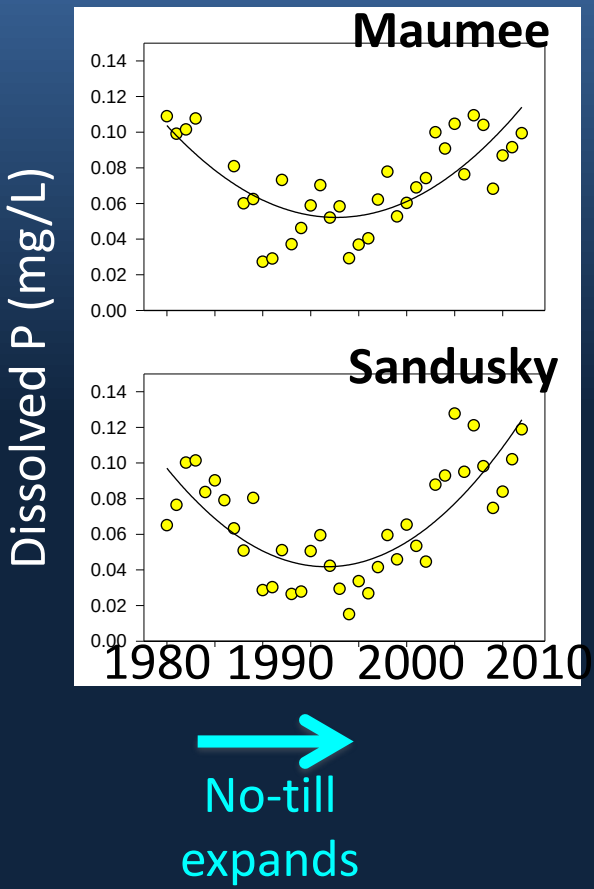


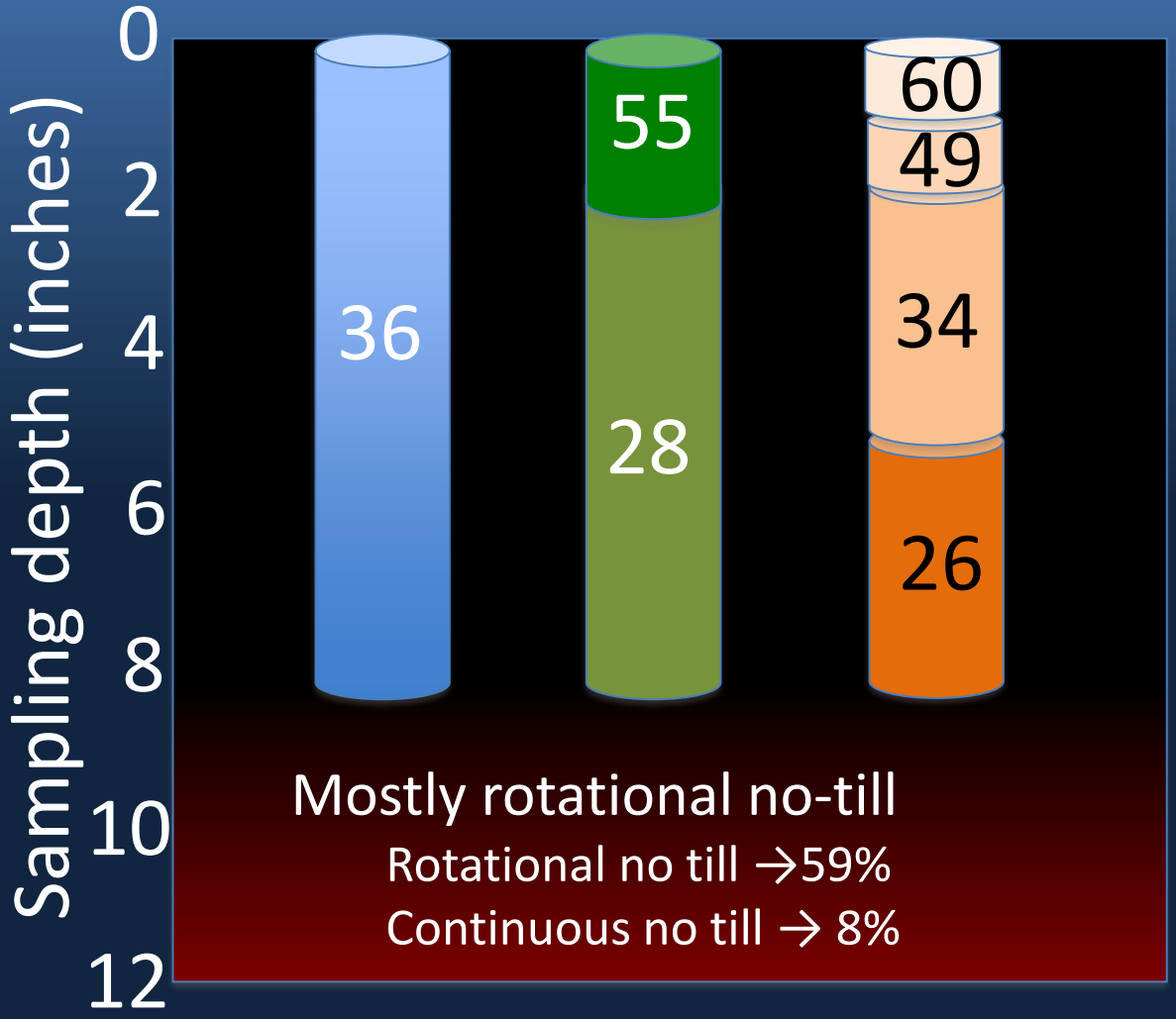
Sharpley and Smith: *J. Environ. Qual., 1994*

Vertical stratification

Vertical stratification of soil P

Can happen quickly



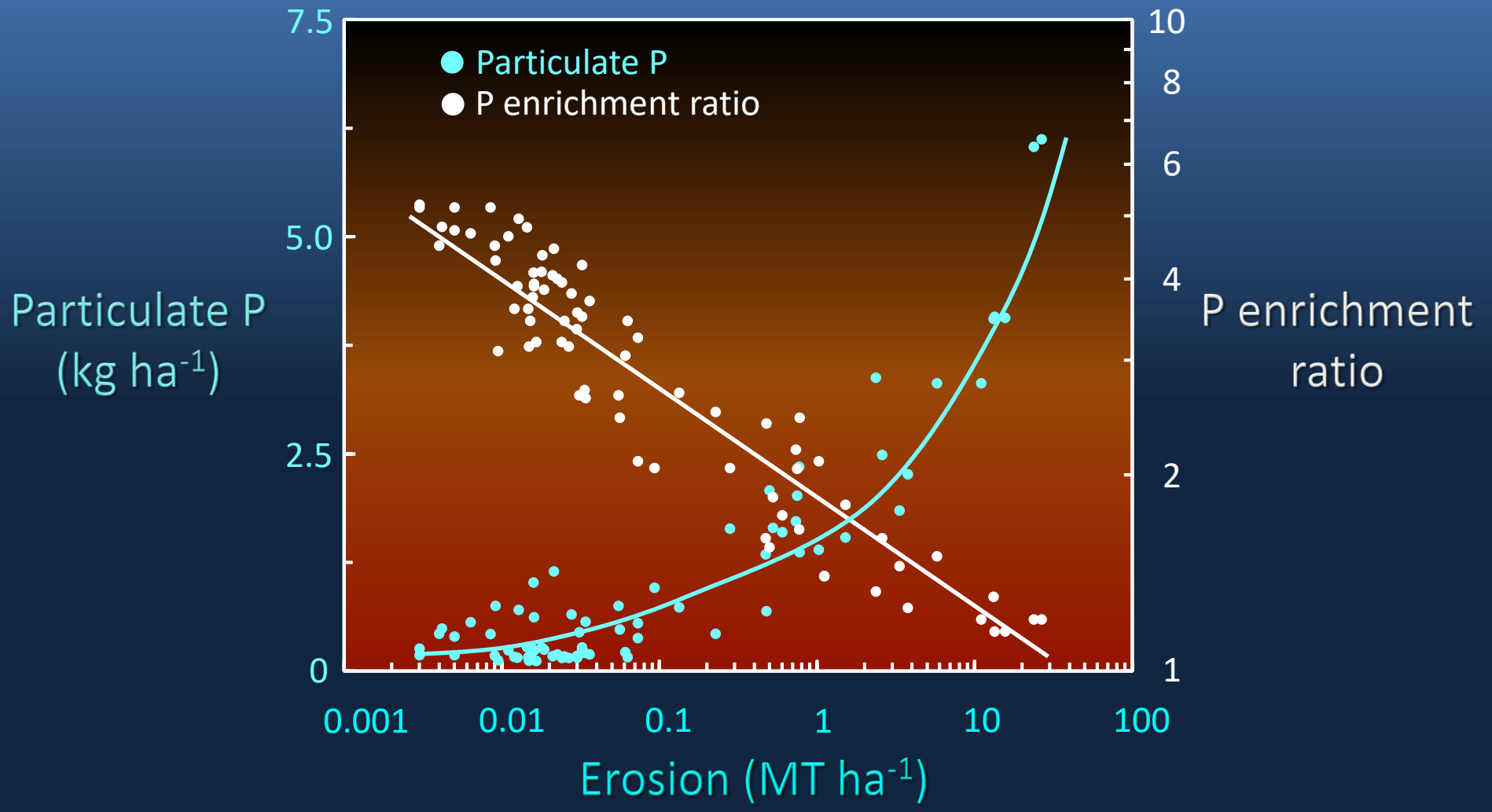


Source: Johnson, Heidelberg U.

P enrichment

Low erosion rates

Yield higher concentrations of particulate P



Sharpley et al., 2002 (J. Soil Water Conserv.)

USDA UNITED STATES DEPARTMENT OF AGRICULTURE

Management lesson # 1

No system is perfectly optimized

Address erosion first

Particulate losses readily overwhelm dissolved P

Vertical stratification happens quickly

Exacerbates dissolved P losses

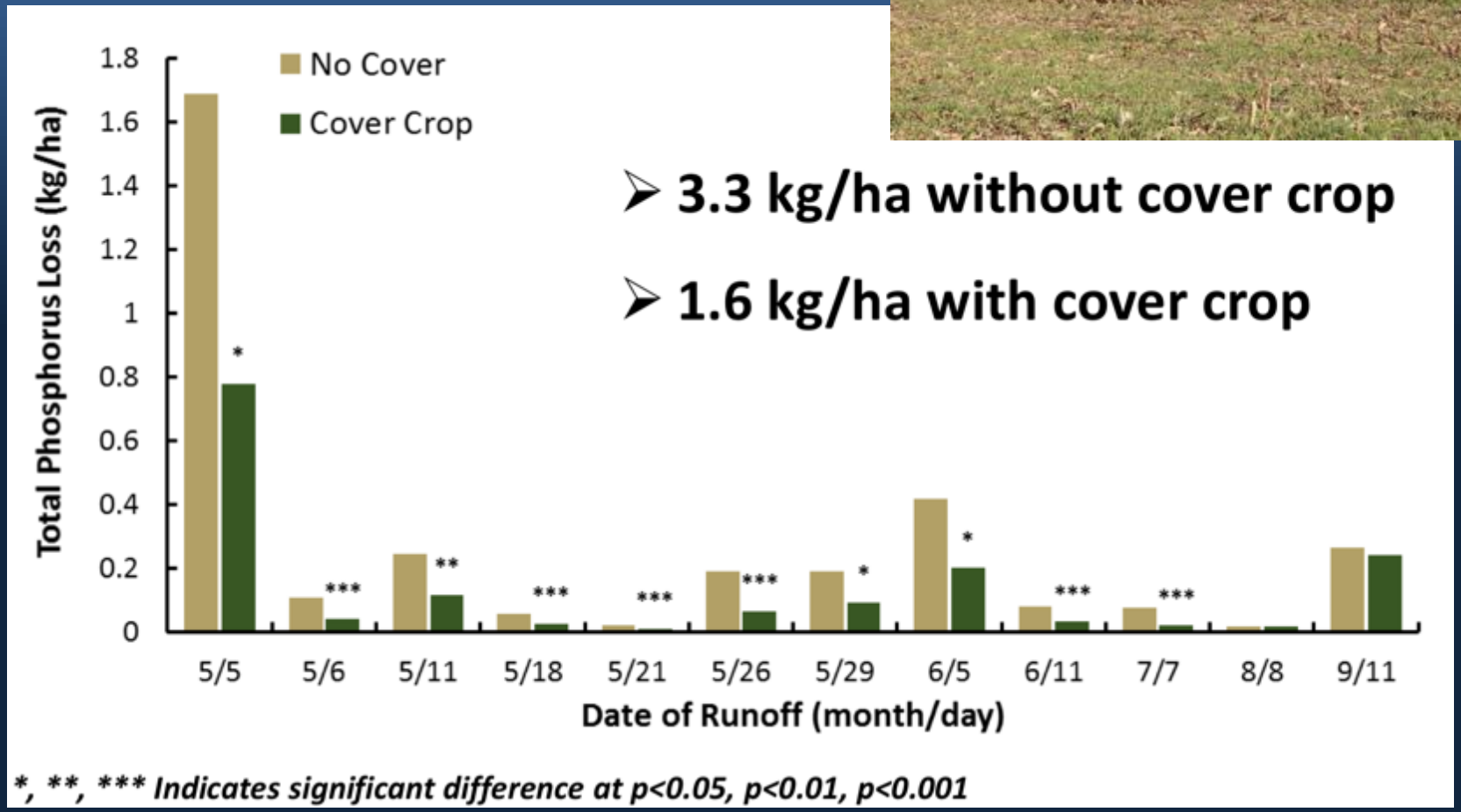
Management

Soil testing,
keeping to recommended levels,
mixing,
subsurface application

Cover Crops

Soil Conservation and nutrient uptake

Kansas study, > 50% reduction in total P loss



Nathan Nelson: Kansas State University

Cover Crops

Lake Erie Paired Watershed Study

Honey Creek Targeted Watershed (2008-2013)

Targeting of cover crops and winter wheat (13.3% of watershed)

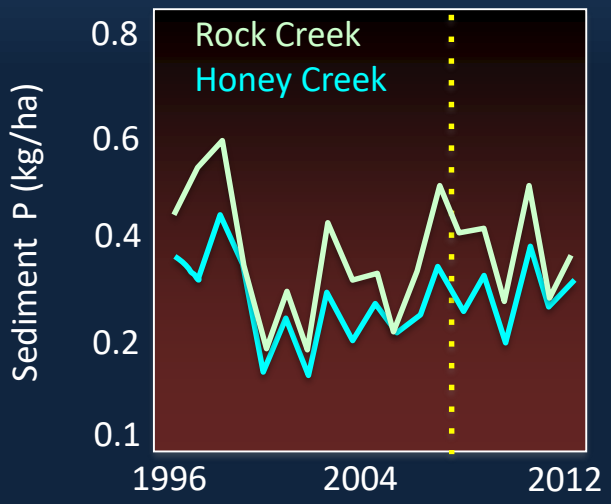
EPA Grant: Heidelberg Univ., Seneca Co. Soil and Water Conservation District, Sandusky River Watershed Coalition, Univ. Toledo, area farmers

Unintended Consequences

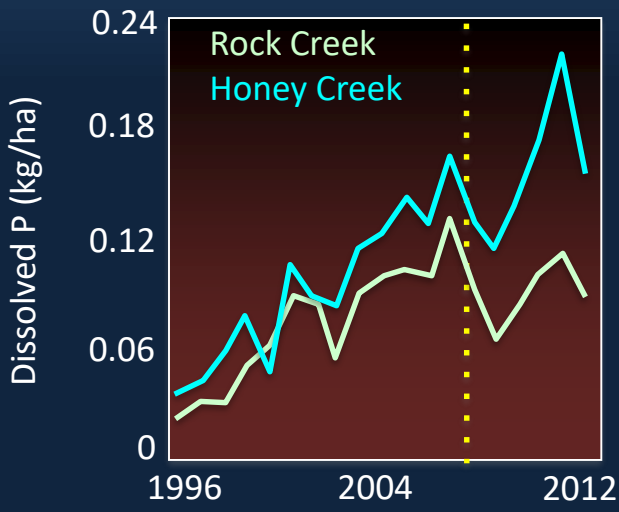
Lake Erie Paired Watershed Study

Honey Creek ("cover crop") vs. Rock Creek ("control")

SEDIMENT BOUND P



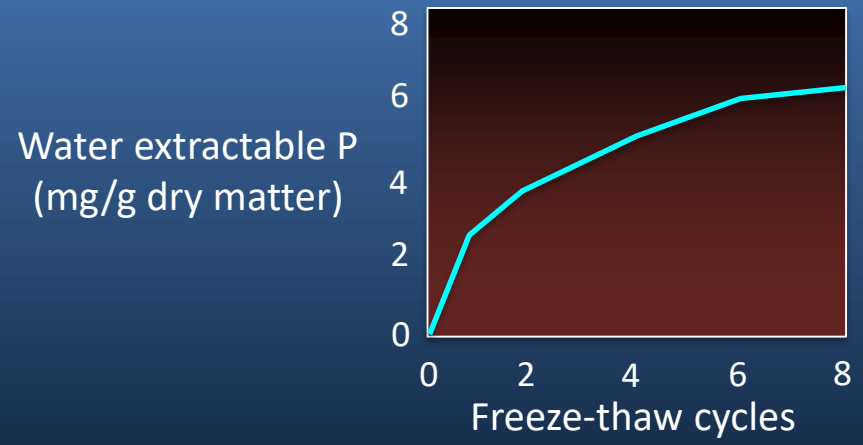
DISSOLVED P

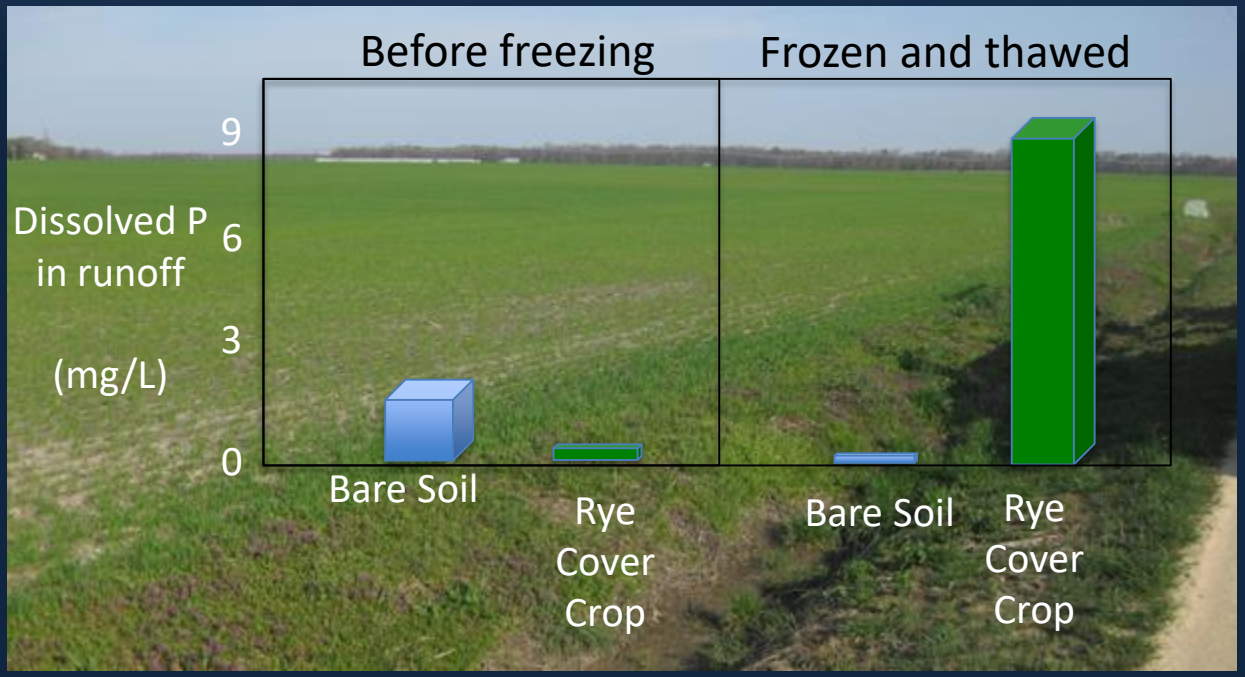


Baker: Heidelberg Univ., 2014

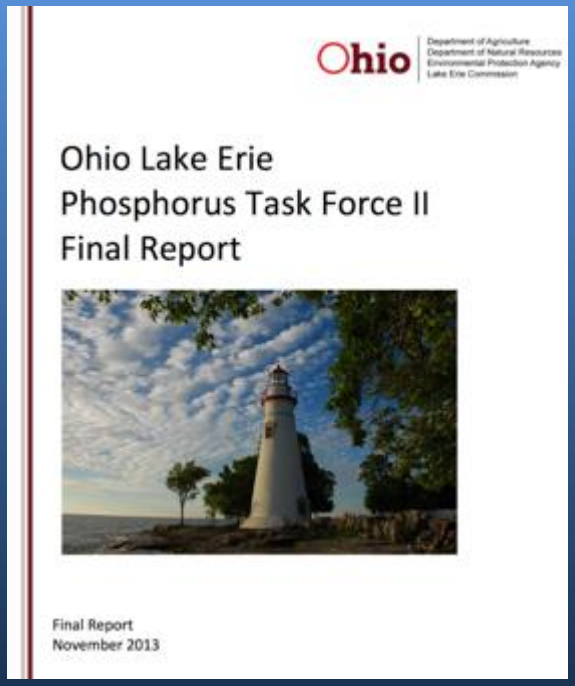
Unintended Consequences

Cover crop – trade offs
a slow release source of dissolved P





Bechmann et al., 2005
J. Environ. Qual.

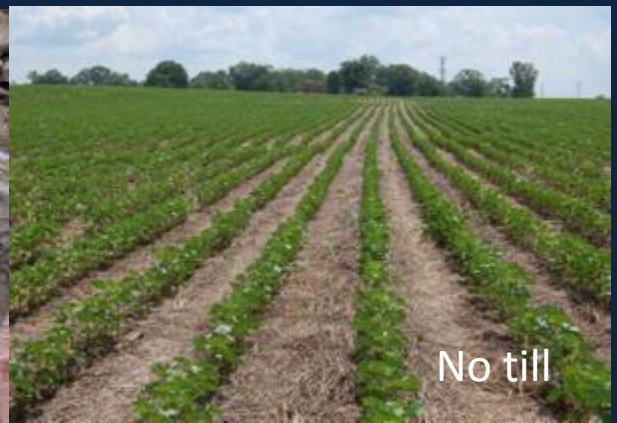


Once the soil is healthy and has good water infiltration and water holding capacity it may be possible to surface apply fertilizer knowing that there will be little or no water runoff and that the nutrients will infiltrate and percolate through the soil via matrix flow.

This will allow the nutrients to interact and bond with the soil. In addition, fertility requirements will likely be lower in a healthy soil due to better nutrient retention and recycling. The overall retention of nutrients and improved soil biota can affect nutrient cycling, may increase efficiency and reduce fertilizer needs.

p. 38


Cover crops

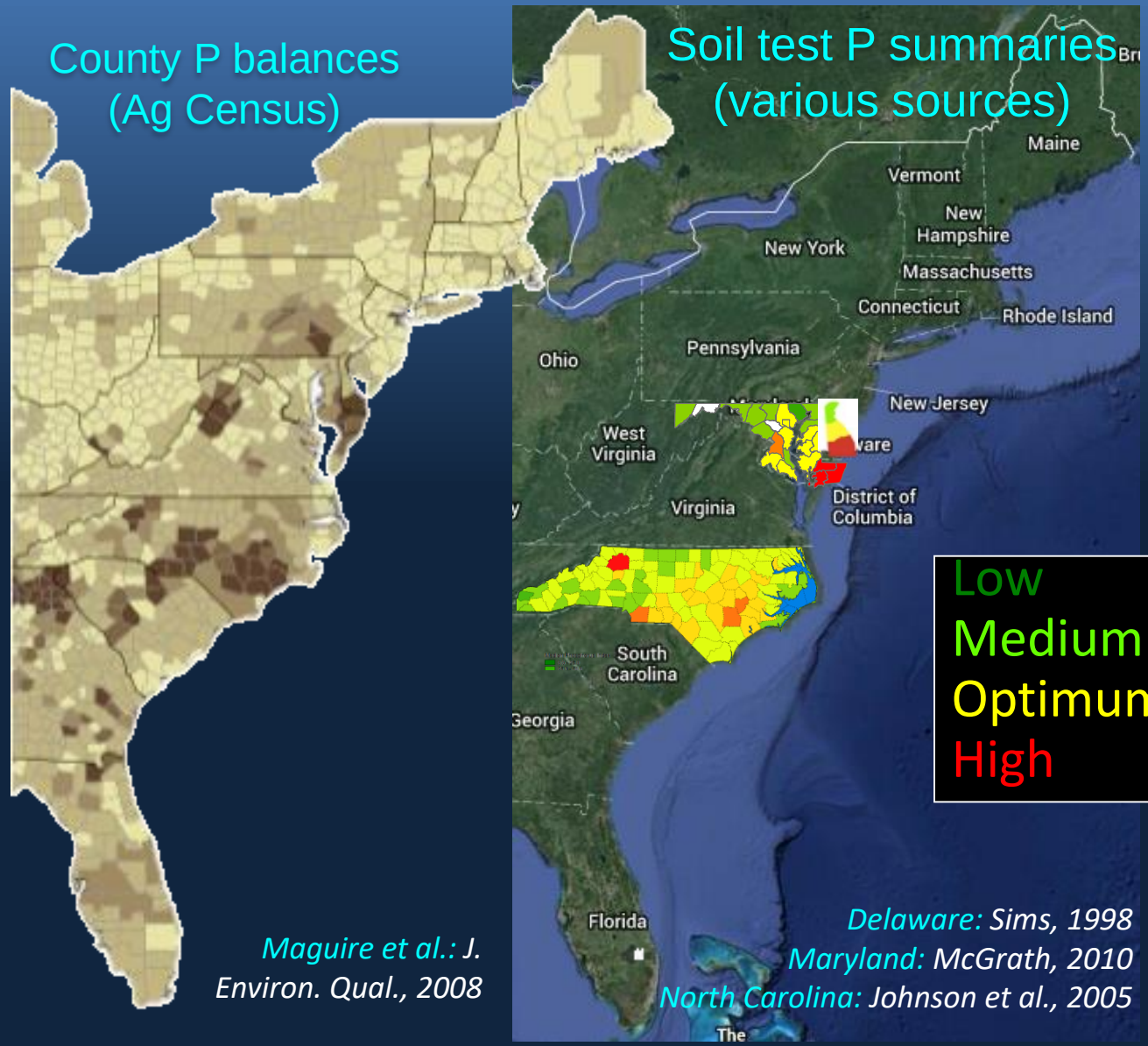

No till

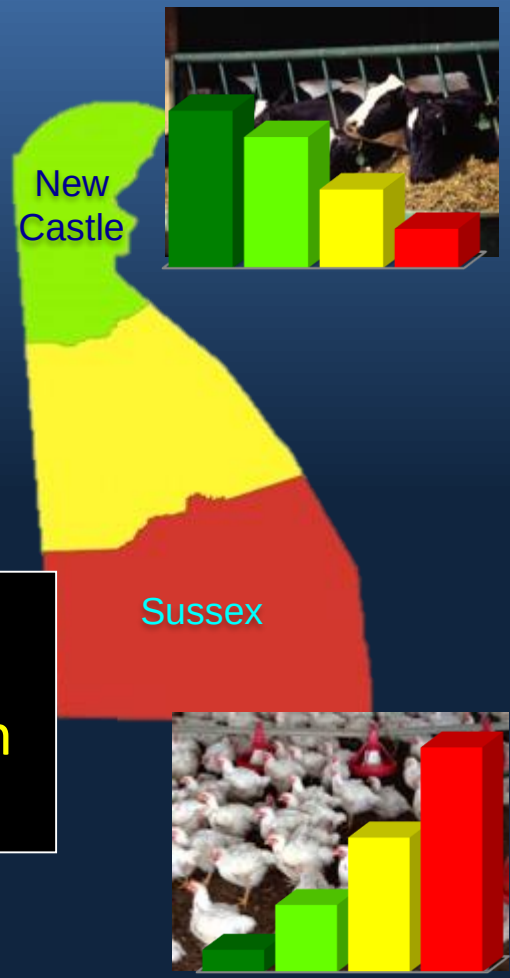
Legacy P

Intensified and specialized farming systems

Disconnect between livestock production and soil P fertility objectives

County P balances (Ag Census)





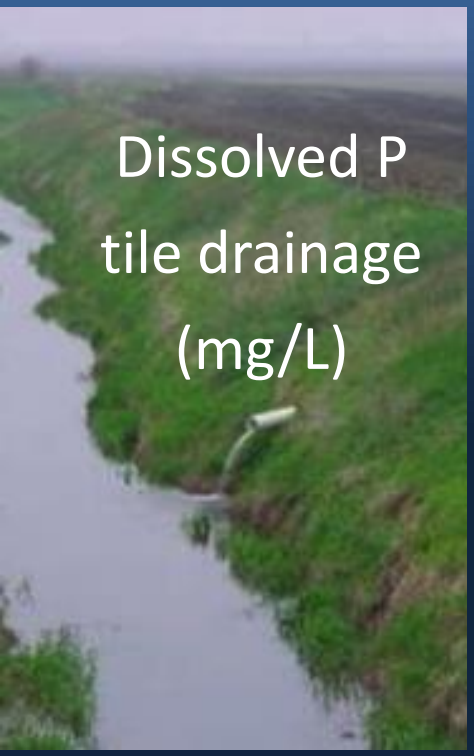
Maguire et al.: J. Environ. Qual., 2008

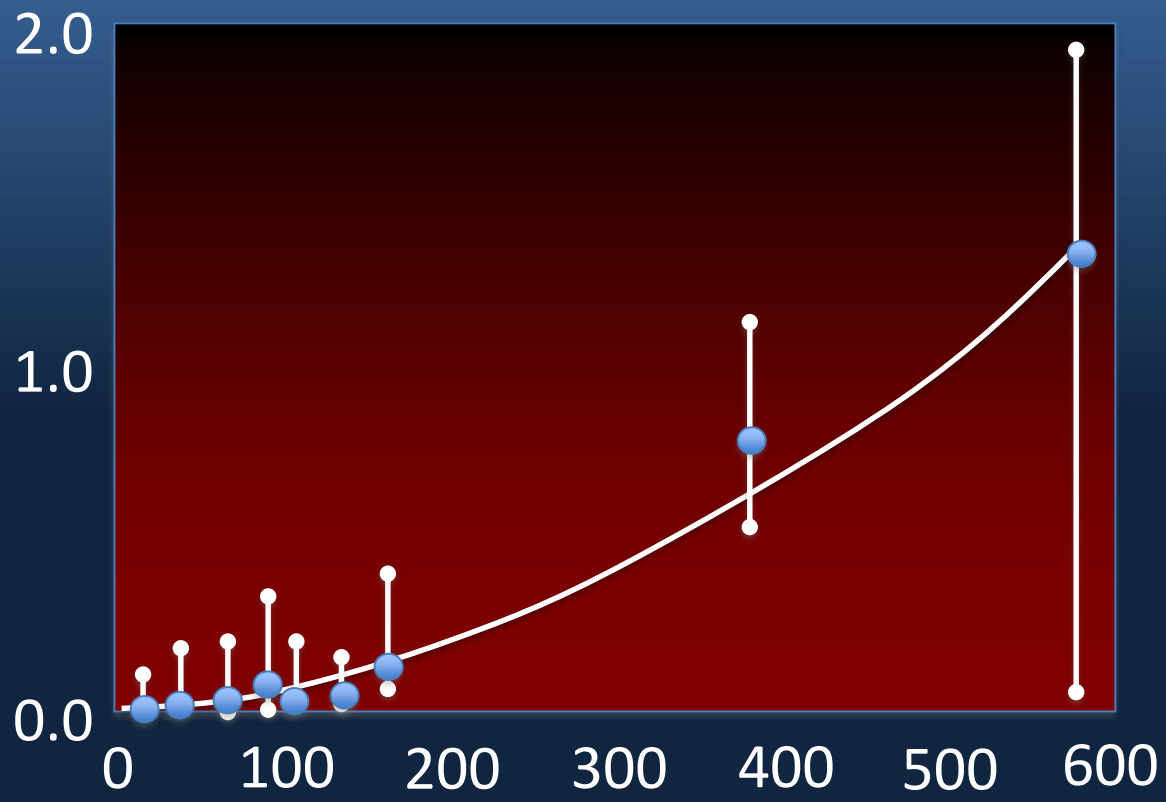
Delaware: Sims, 1998
Maryland: McGrath, 2010
North Carolina: Johnson et al., 2005

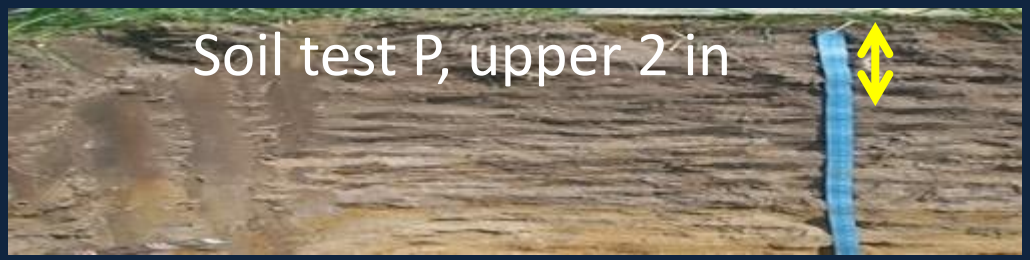
Sims et al.: J. Environ. Qual., 1998

Drainage and subsurface P loss

Similar findings to surface runoff



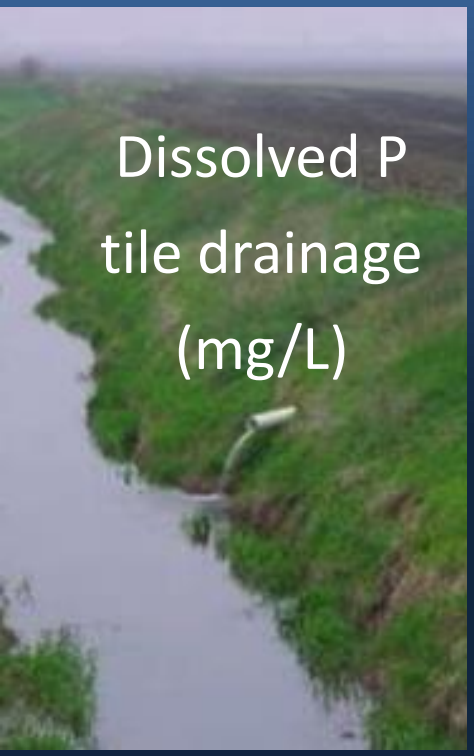


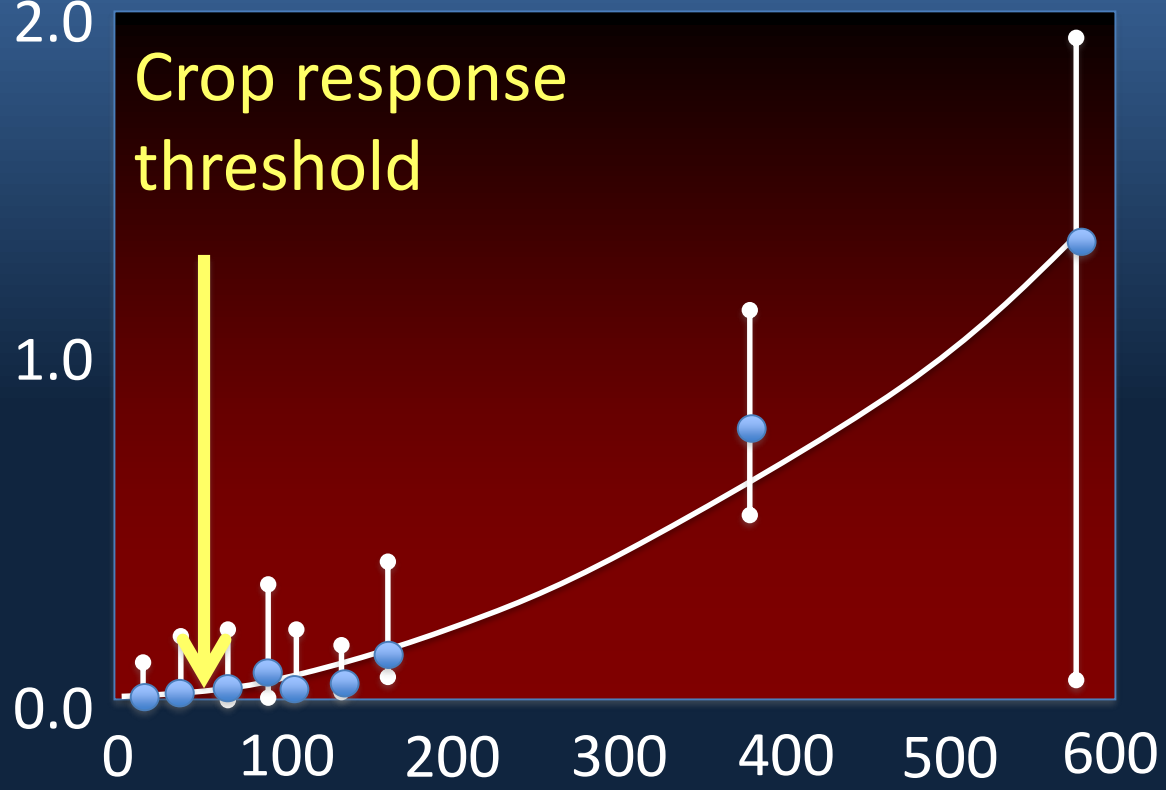


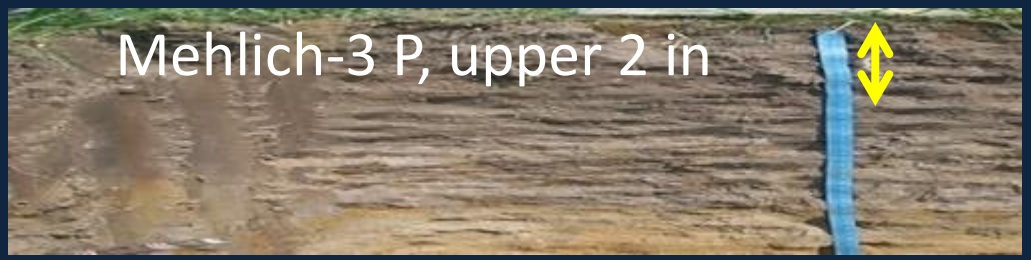
Source: King, USDA-ARS

Drainage and soil P

Follow land grant university recommendations



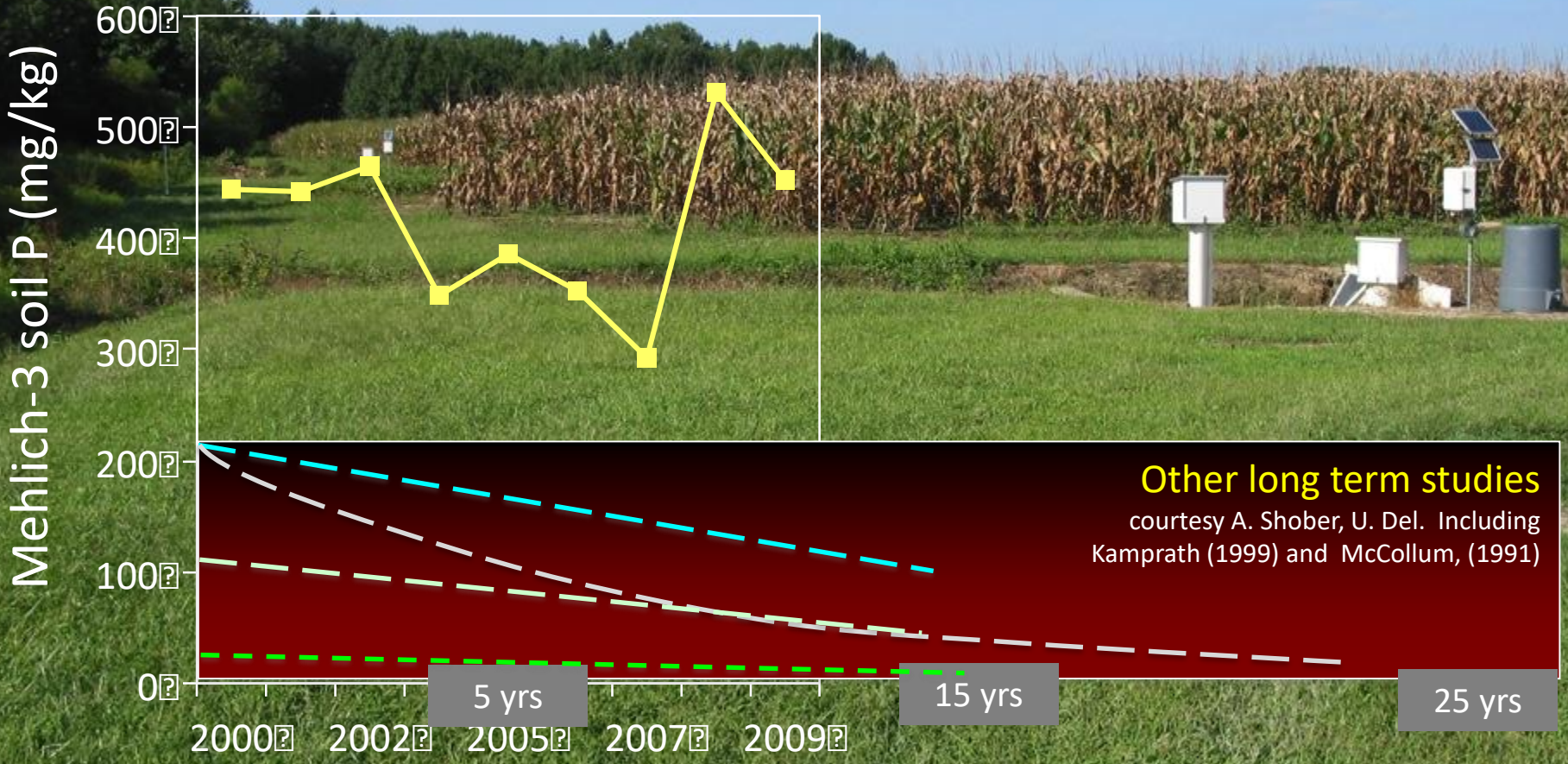




Source: King, USDA-ARS

"Mining" legacy P

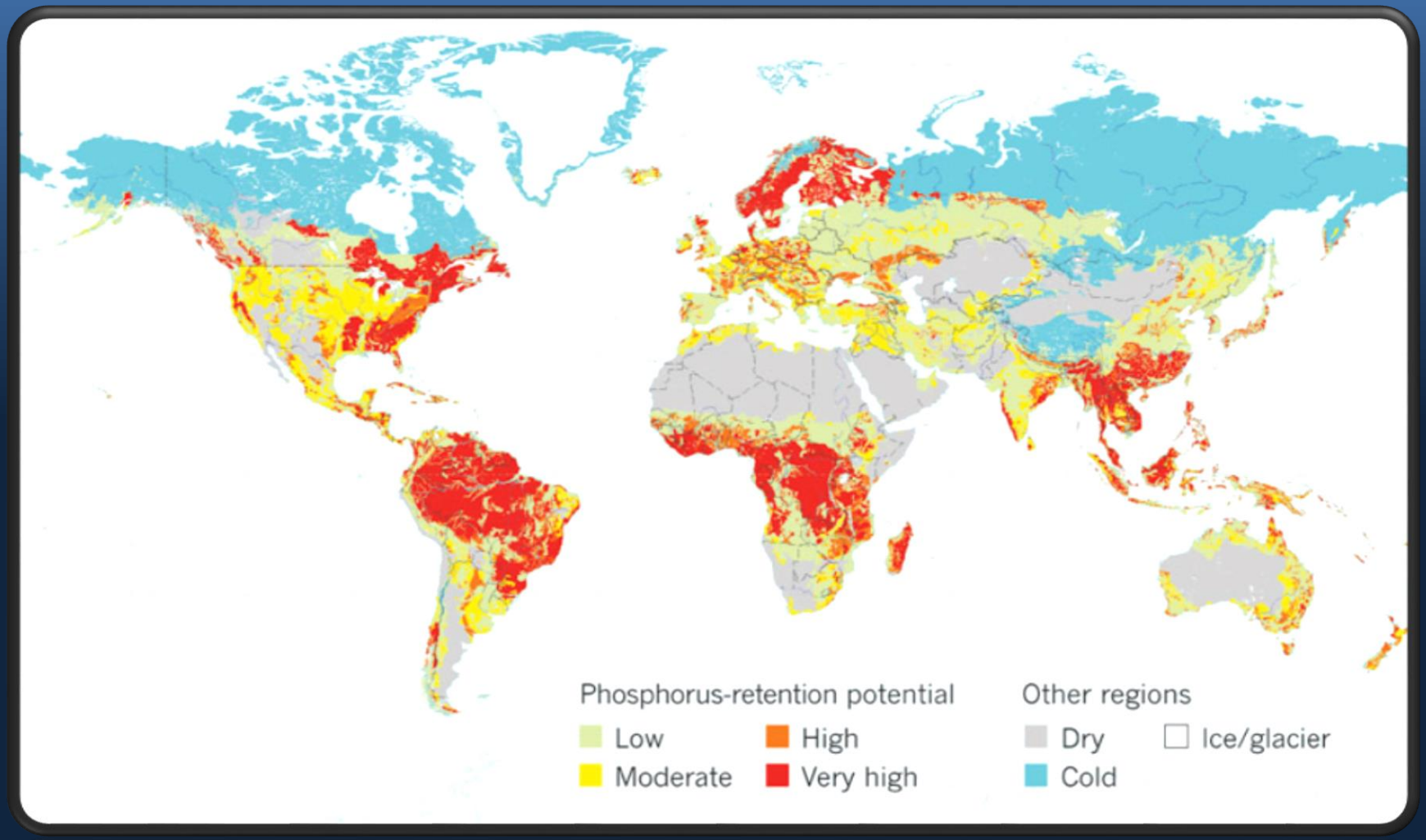
Don't let it build up in the first place!



Kleinman et al., 2010 (Canadian J. Soil Science)

P fertility

Many of the world's agricultural soils have high P binding potential

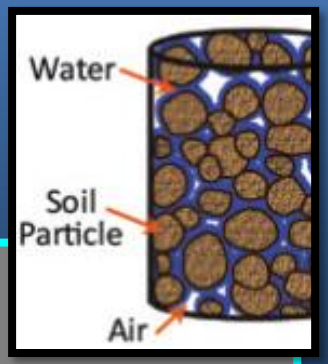


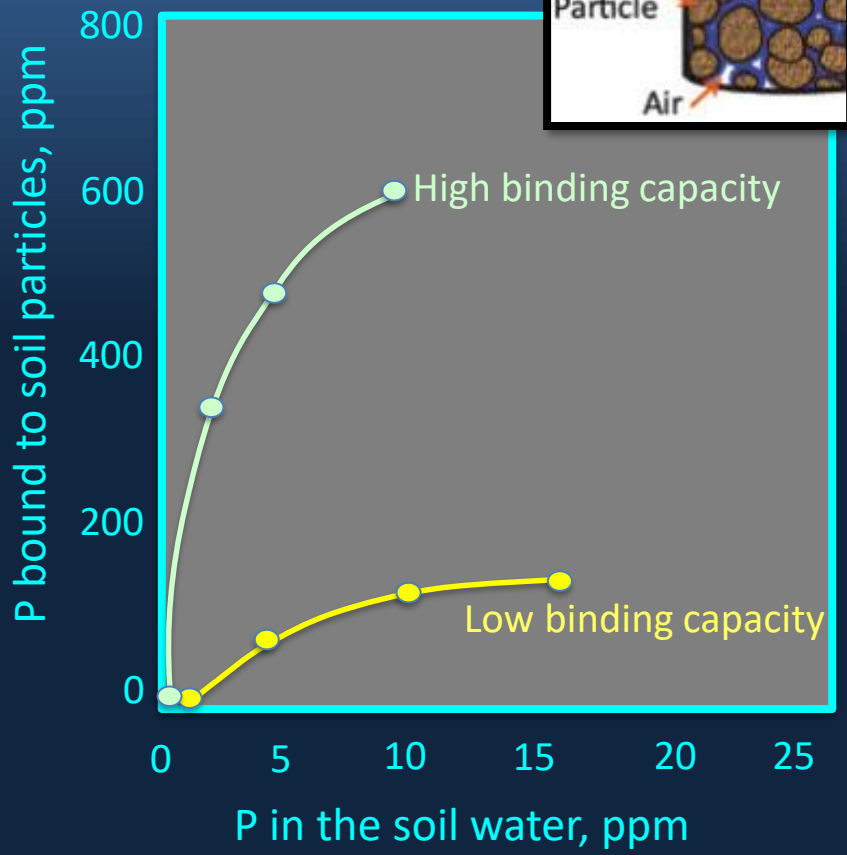
Kochian: Nature, 2012

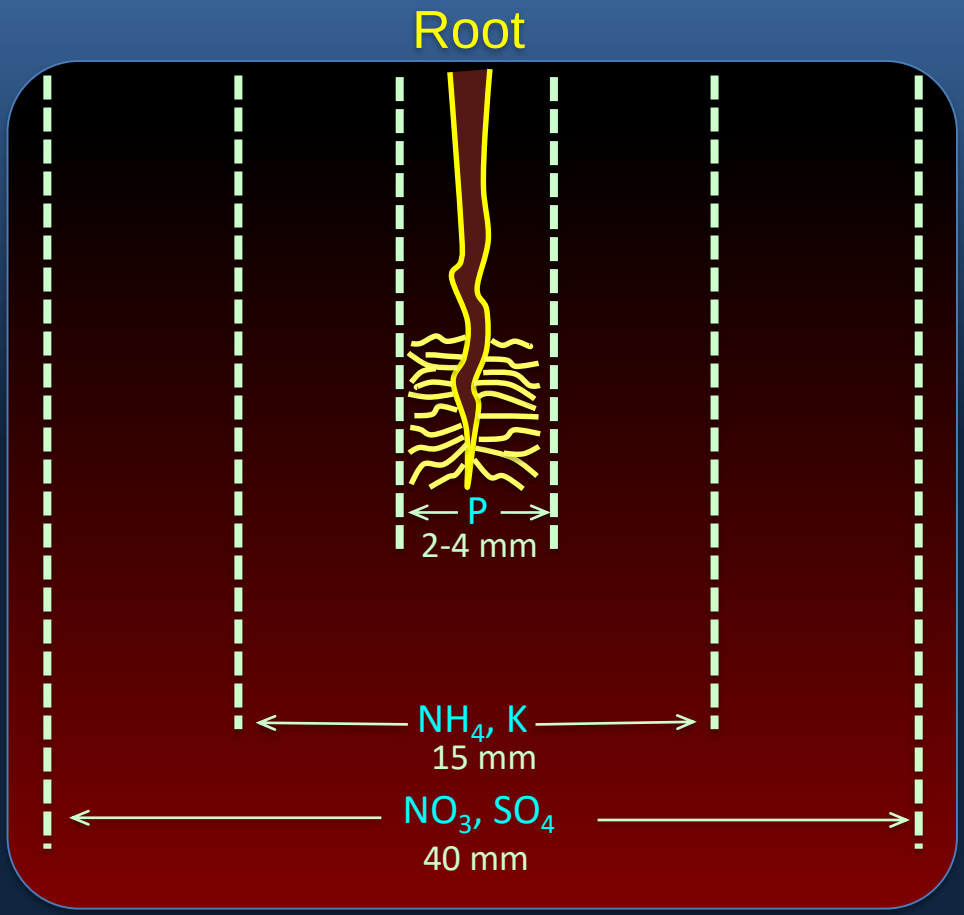
P fertility

Overcoming P binding (sorption)

Most fertilizer P is bound by soil particles

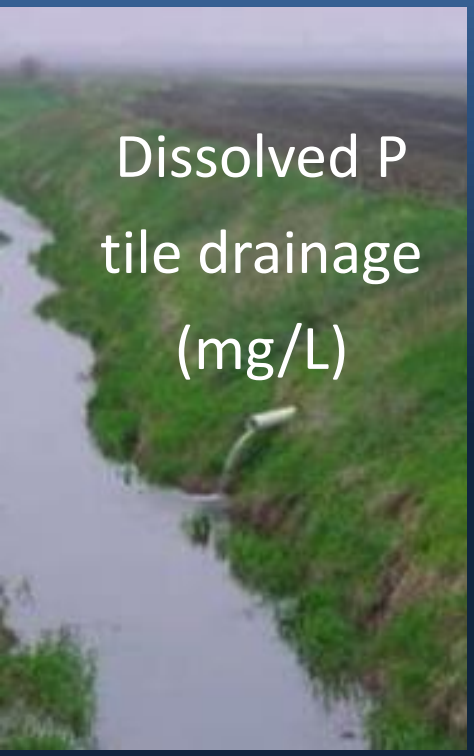


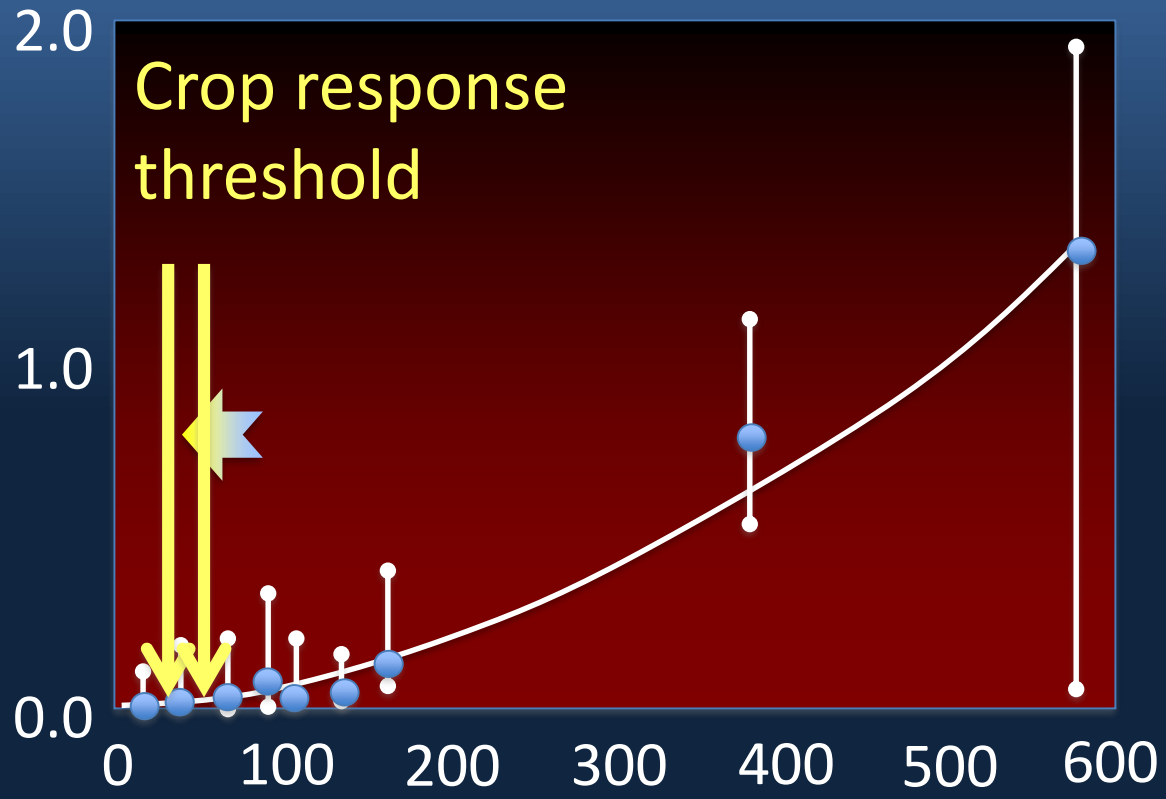


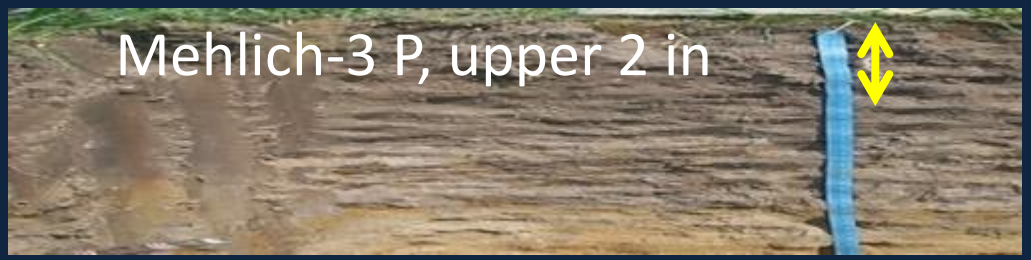


Drainage and soil P

Follow your land grant university recommendations







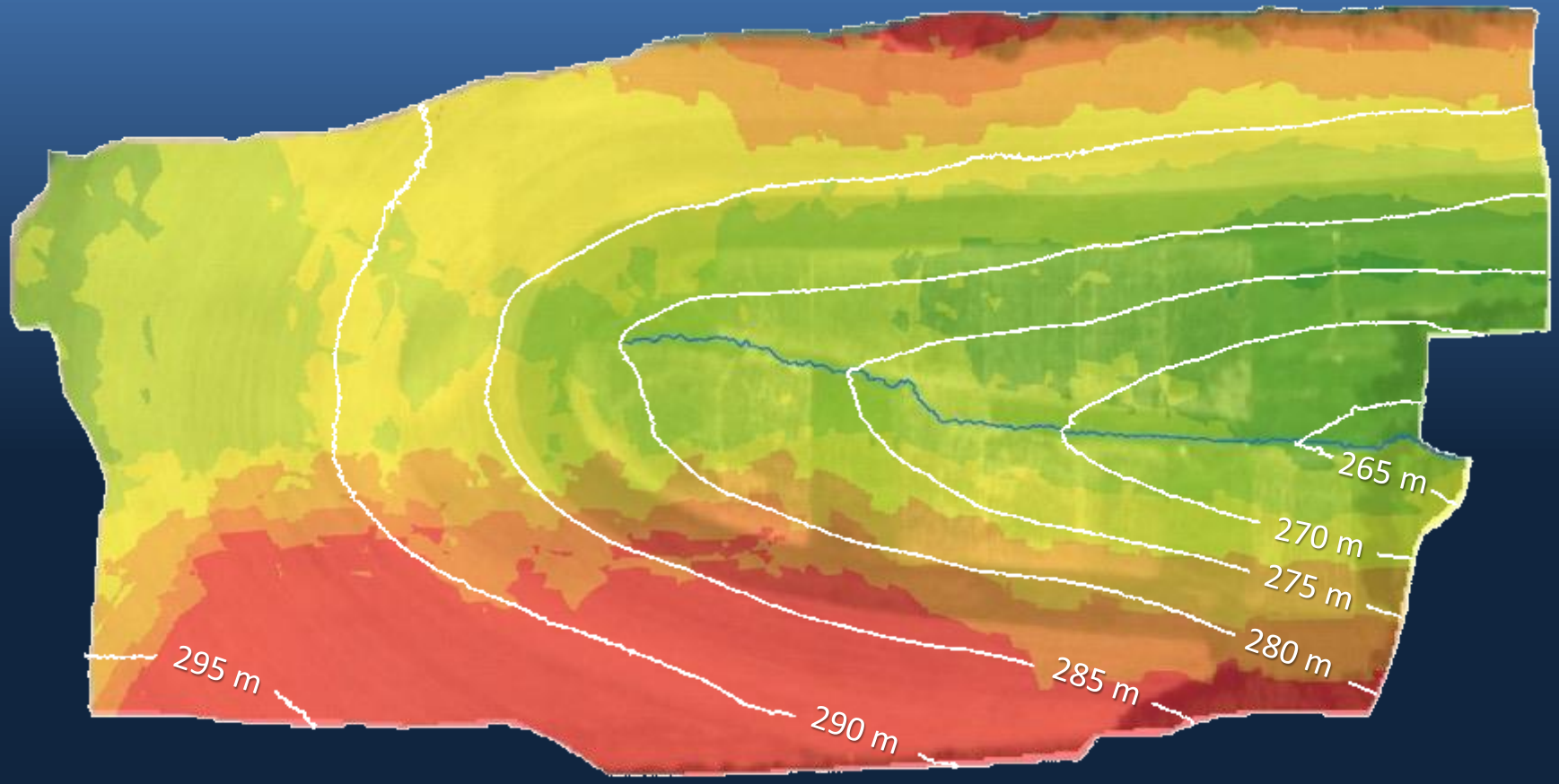
Source: King, USDA-ARS

Connecting the dots

moving P from the landscape progressively downstream

High P soils represent a P source to runoff

key factor is the hydrological connectivity with P source areas

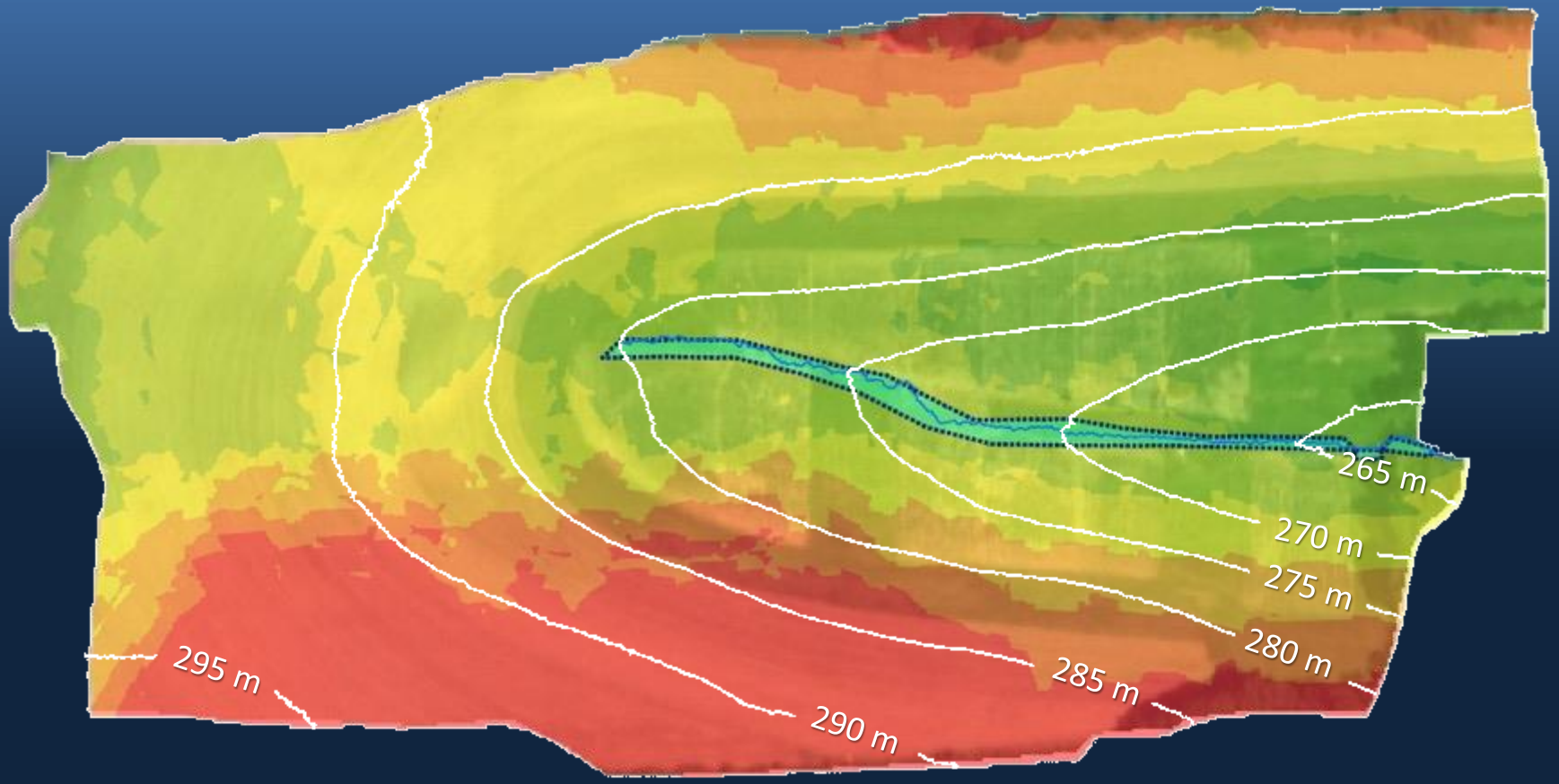


Mehlich-3 soil P (mg/kg)

150 200 250 300 350 400

The contributing area for Irene was small

only 0.4% of watershed was likely generating runoff and P loss

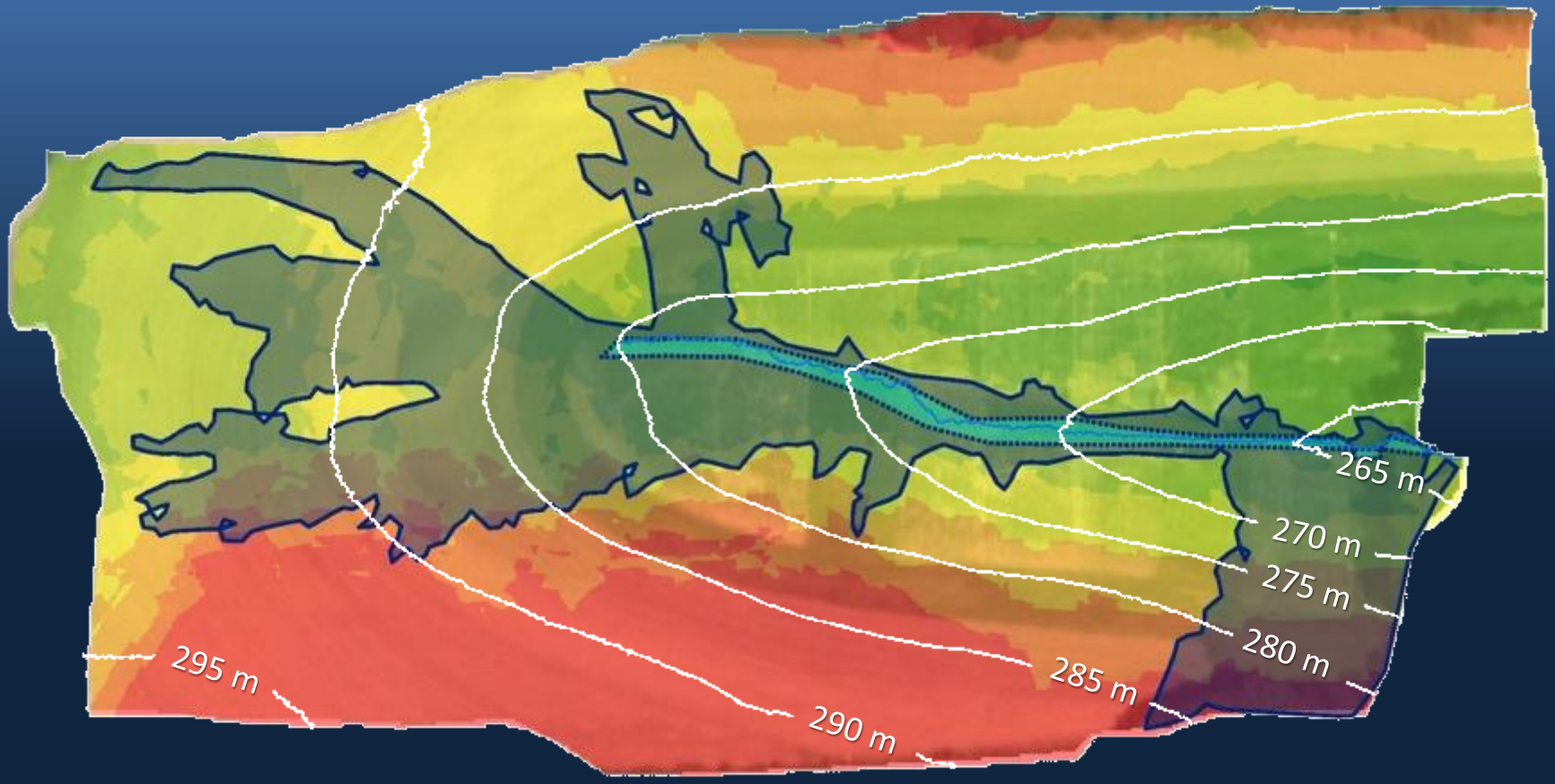


Mehlich-3 soil P (mg/kg)

150 200 250 300 350 400

The contributing area for Lee was larger

as much as 28% of the watershed generated runoff and P loss

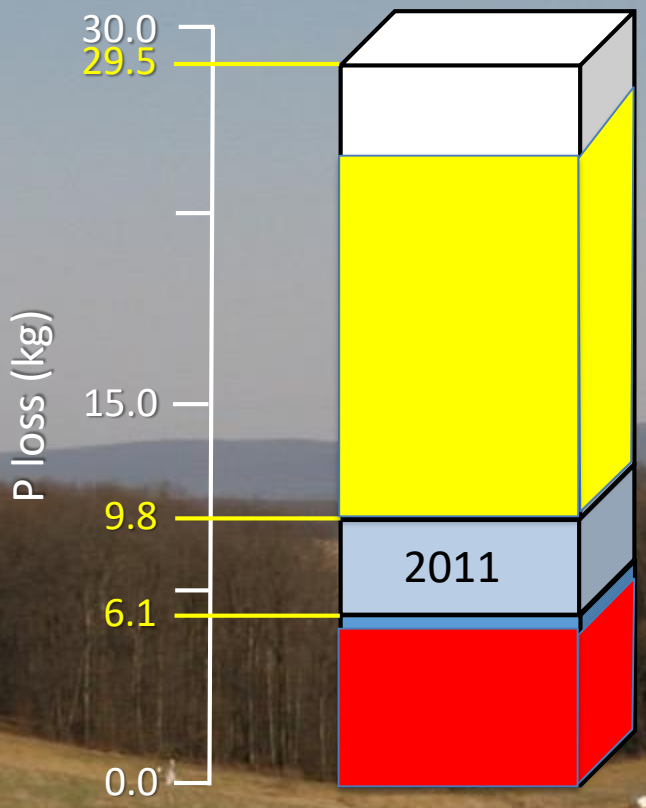


Mehlich-3 soil P (mg/kg)

150 200 250 300 350 400

P loss from Tropical Storm Lee was profound

Lee contributed significantly to 2011 and decadal P loss

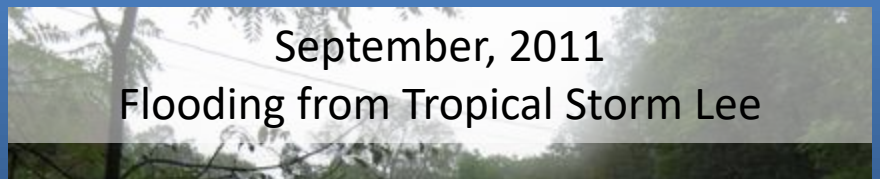


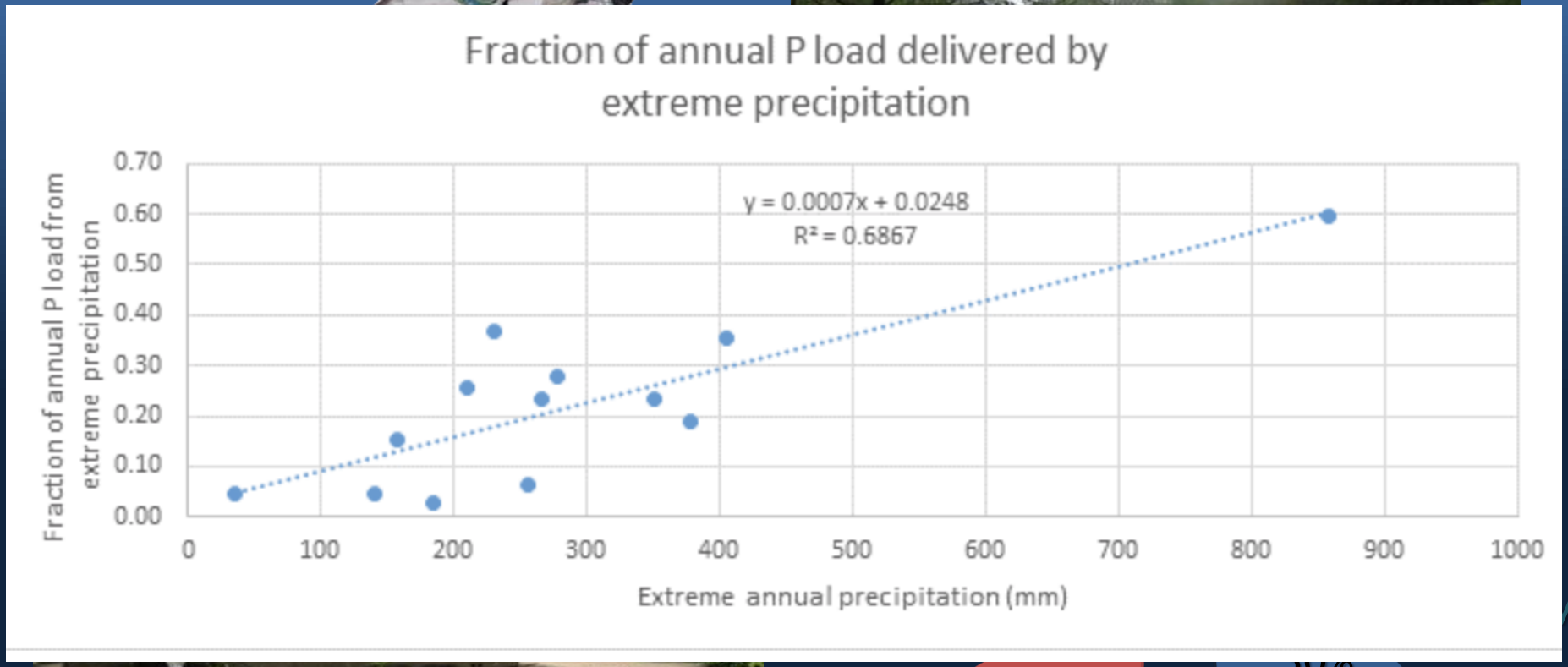
Tropical Storm Lee accounted for 21% of the P loss over the past decade.

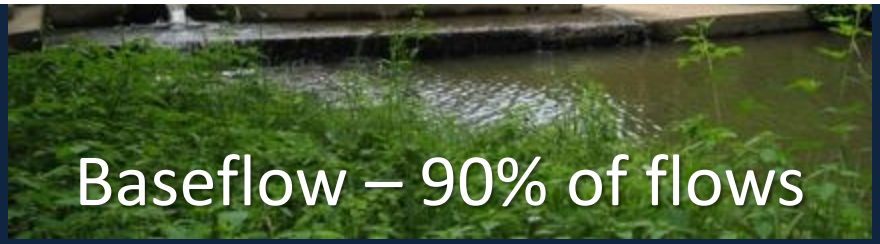
Tropical Storm Lee accounted for 63% of the P loss in 2011.

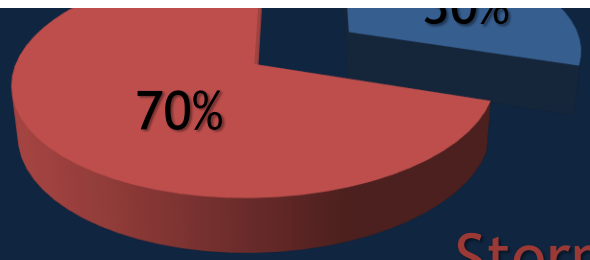
Annual P export is a function of storm size

WE-38 watershed









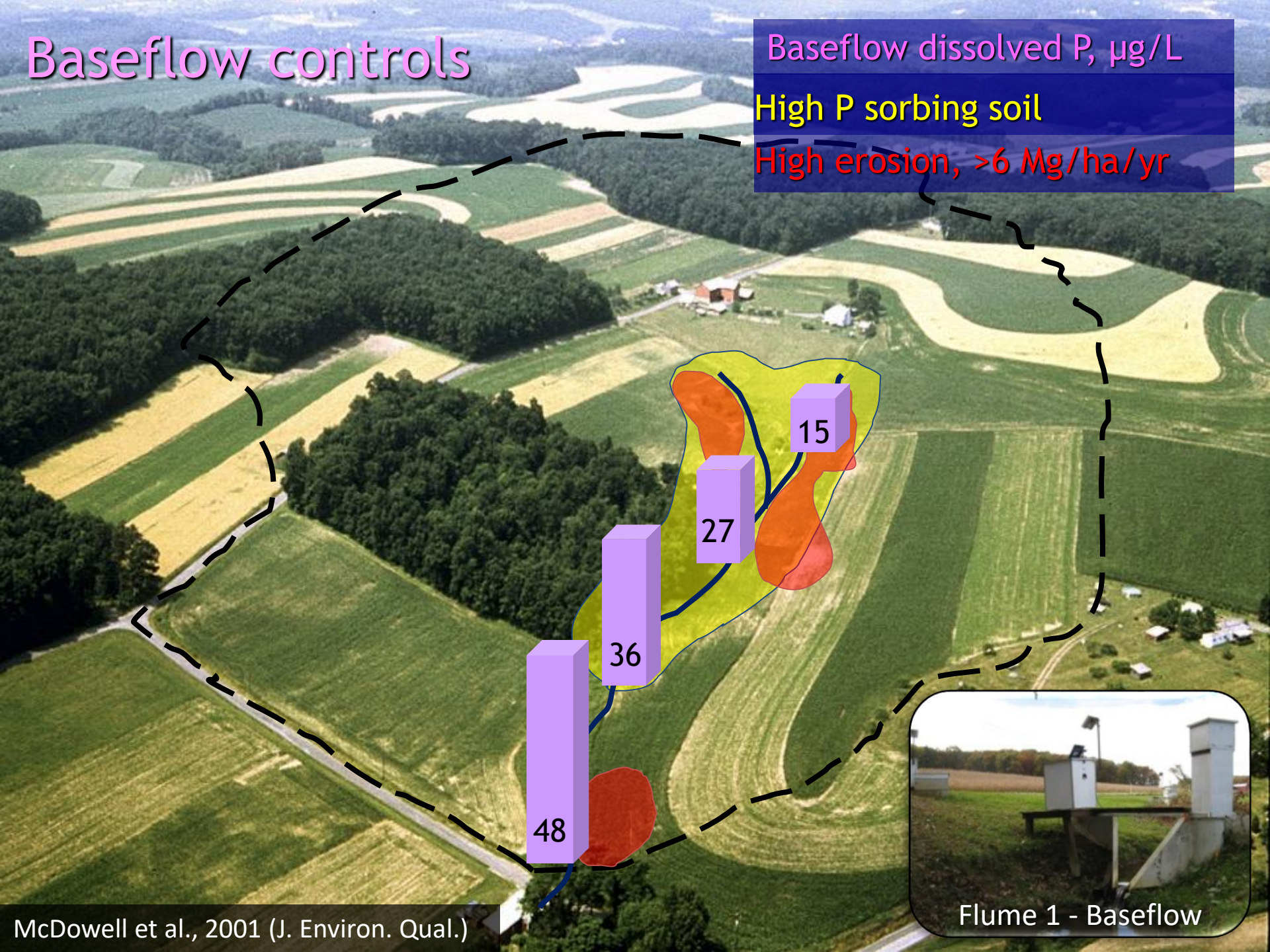
Pionke et al., 1996 (Water Resources Research)

Baseflow controls

Baseflow dissolved P, µg/L

High P sorbing soil

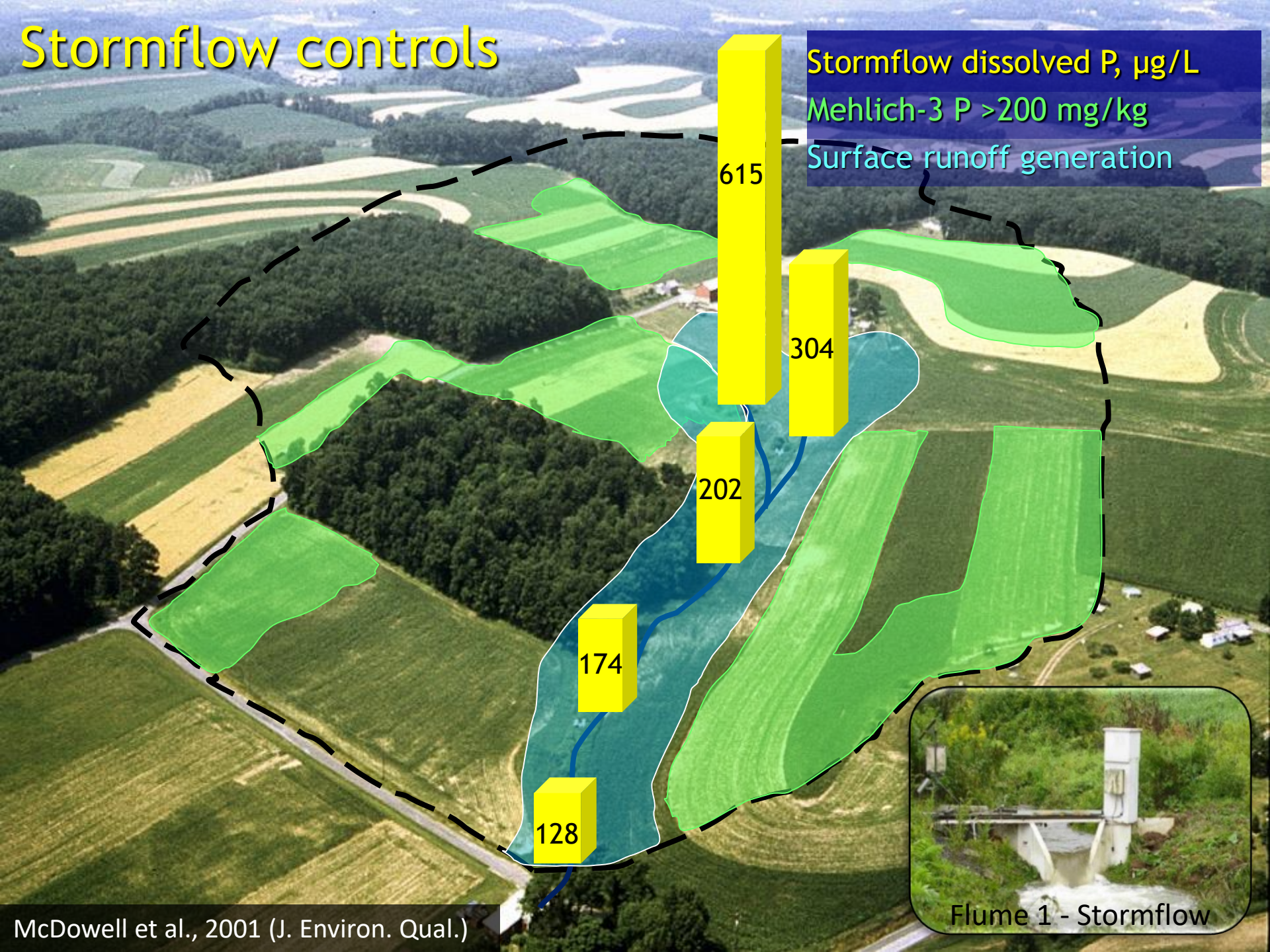
High erosion, >6 Mg/ha/yr



Flume 1 - Baseflow

McDowell et al., 2001 (J. Environ. Qual.)

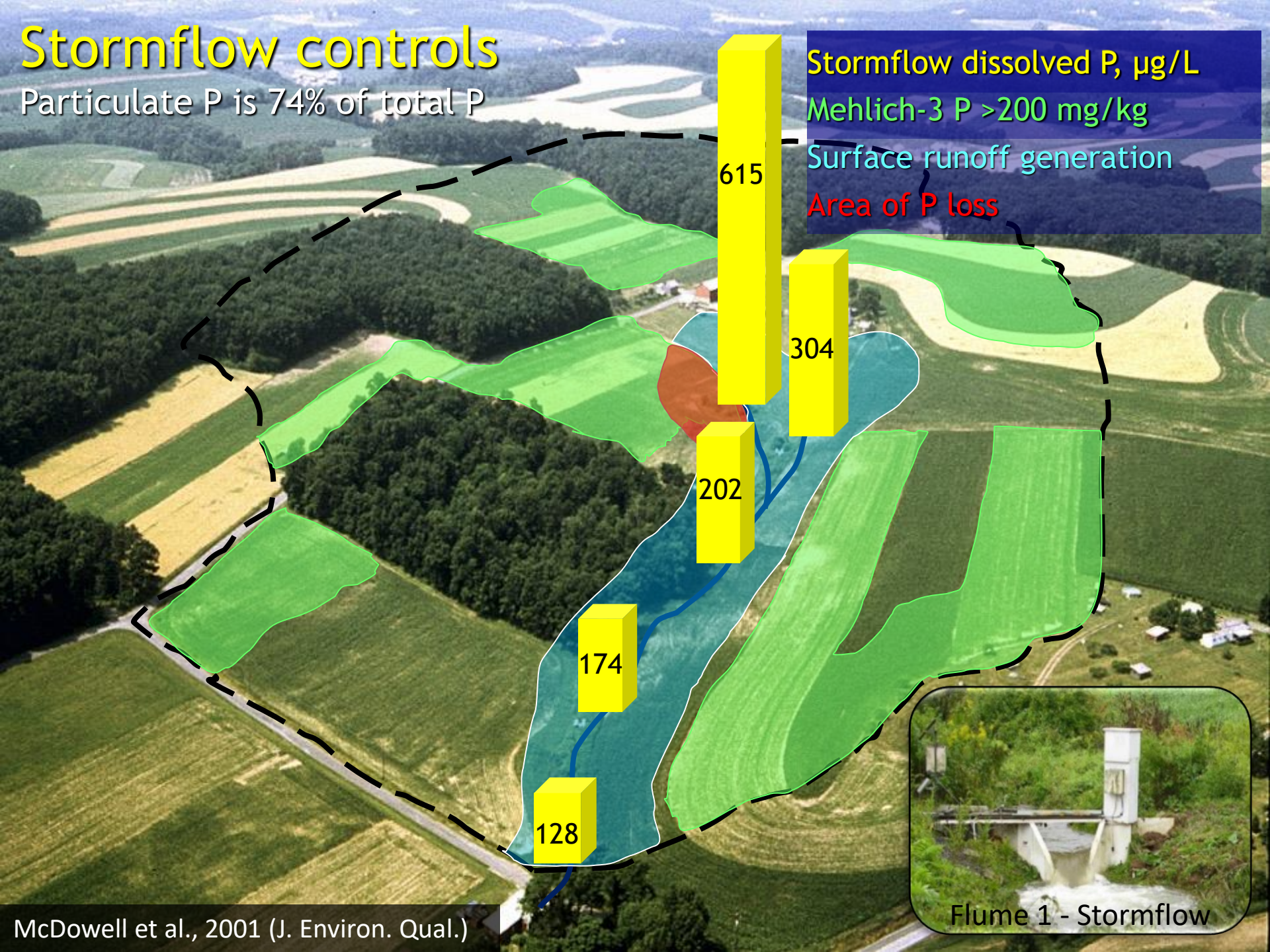
Stormflow controls



McDowell et al., 2001 (J. Environ. Qual.)

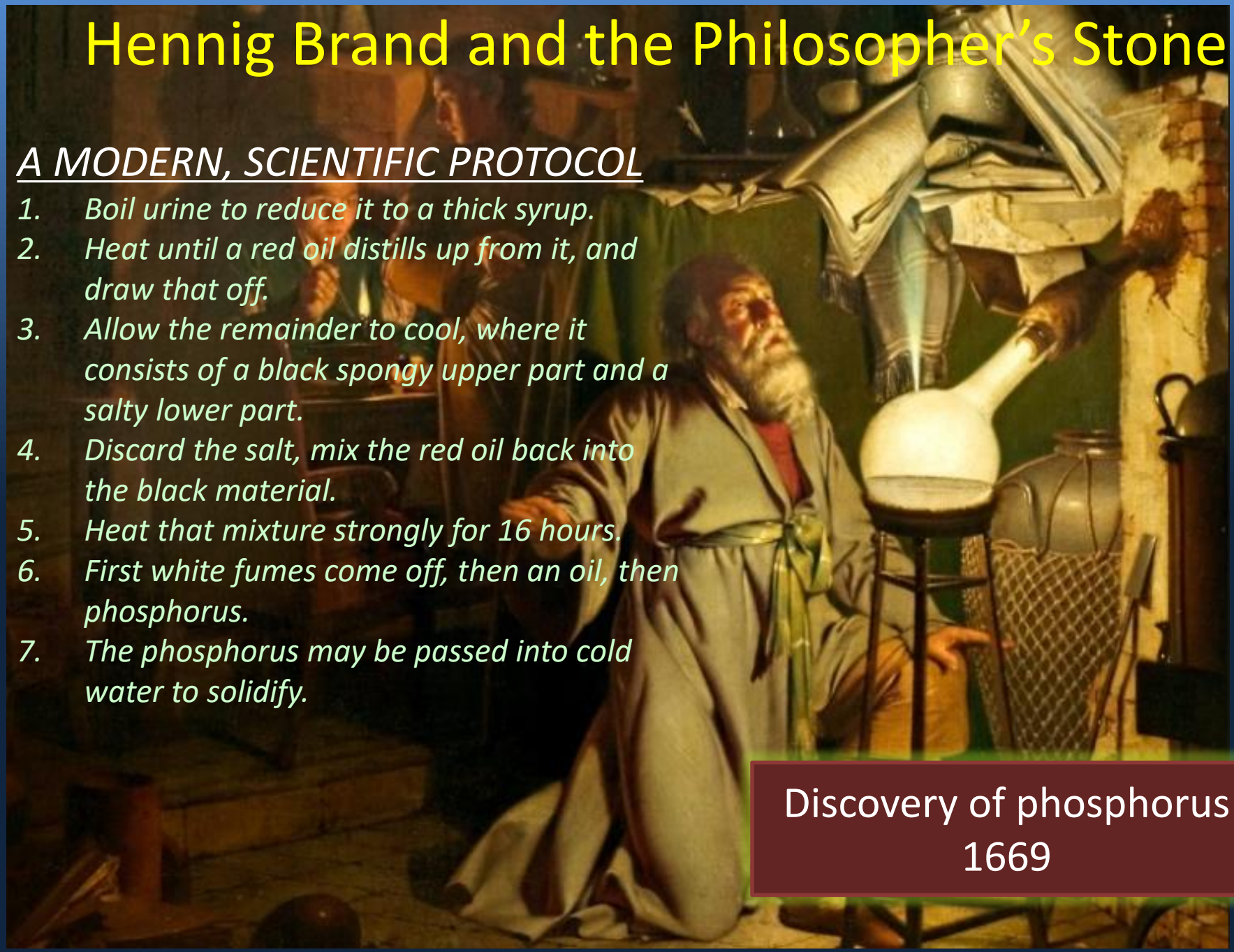
Stormflow controls

Particulate P is 74% of total P



McDowell et al., 2001 (J. Environ. Qual.)

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
1669

peter.kleinman@ars.usda.gov