Conservation trade-offs and legacy P

USDA’s Legacy Phosphorus Assessment

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Conservation trade-offs
Well documented, not new, but always relevant

Effect on dissolved P loss, %
- Decreased loss
- Increased loss

Manure mgt. system (14)
-28%

Nutrient mgt. plan (14)
-40%

Riparian / strip buffers (34)
-20%

Conservation tillage (13)
+5%

Nutrient mgt. plan (14)

-100 $\rightarrow$ Decreased loss 0 Increased loss $\rightarrow$ 100

Effect on dissolved P loss, %
Conservation 101

Conservation practices are managed as part of a system

Avoid

- the RIGHT SOURCE of P applied
- in the RIGHT PLACE
- in the RIGHT AMOUNT
- at the RIGHT TIME

Control

- Conservation tillage can reduce P loss in runoff
- Cover crops can reduce P loss in runoff and increase infiltration
- Buildup of soil P and crop residue at surface can be a source of P to runoff
- Cover crops can be a source of P in runoff

Trap

- Vegetative buffers can trap particulate P and take up some soluble P
- Wetlands can trap particulate P and take up some soluble P
- Wetlands and vegetative buffers can transition from being a sink to source of P to runoff
- Treatment of wetlands and buffers with waste byproducts that can bind P may decrease P runoff

Frequent soil and manure testing, subsurface injection, and avoiding application to areas prone to runoff and erosion, will maximize crop uptake while reducing runoff and leaching

Subsurface injection reduces potential for P runoff
In-field management of cover crop can reduce potential for P runoff
Conservation practices

*Traps*

- Vegetated filter strips
- Grassed waterways
- Riparian forest buffers
- Conservation terraces
- Restored wetlands
- Water and sediment control basins

![Conservation practices images](images)
Conservation practices

Trapping processes

- Impound runoff
- Diffuse flow
  - Promote infiltration
- Sedimentation
- Biological uptake, soil processes
Trapping practices
Performance modifying processes

Extreme events
Concentrated flows
Scouring, resuspension
"Reductive dissolution"
Phosphorus saturation

Dissolved P, dissolved P, dissolved P, dissolved P, dissolved P
History overwhelming sources
Restored wetlands

P saturation, reductive dissolution, biological cycling

• Dissolved P release during wetland restoration
Vegetative buffers as a BMP for P

Global review

Phosphorus Retention in Riparian Buffers: Review of Their Efficiency

2009

BMP effectiveness

Total P removal

+93%  +32%

Lower P loss  Greater P loss

BMP effectiveness

Dissolved P removal

+95%  -71%

Lower P loss  Greater P loss

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Phosphorus Retention in Riparian Buffers: Review of Their Efficiency

Carl Christian Hoffmann, Charlotte Kjærgaard, Jaana Uusl-Kämppä, Hans Christian Bruun Hansen, Brian Kroonvang

Vegetative buffers as a dissolved P source

Cold climates

Water extractable P

$\text{mg/g dry matter}$

Number of freeze/thaw cycles

[Graph showing the relationship between water extractable P (mg/g dry matter) and the number of freeze/thaw cycles.]
Vegetative buffers as a dissolved P source

A legacy of historical management

Chesapeake Survey

Soil P status of CP-22 buffers looks just like it did when the site was converted from production.
Legacy P

What is it?

Residual P in the environment accumulated over decades/centuries of human activity

Where is it found?

- Soils
- Streams & Floodplains
- Small Impoundments
- Reservoirs
- Groundwater

P Cycle

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Role of legacy P in watershed outcomes
Strategies to address legacy P

Conservation Effects Assessment Project

USDA Legacy P Project:

Snake River
Upper Mississippi
Western Lake Erie
Lake Champlain
Upper Chesapeake
Upper Chesapeake
Lower Chesapeake
Lower Mississippi

Basin name:
- Chesapeake Bay
- Lake Champlain
- Lake Erie
- Mississippi River
- Snake River
Legacy P - long term build up, long term decline

Manifest in soils, sediments and, ultimately, water

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

Other long term studies
Legacy P
Can derive from unremarkable sources

High soil phosphorus levels
\( M_3-P \sim 150 \text{ mg/kg} \)

Moderate soil phosphorus levels
\( M_3-P \sim 75 \text{ mg/kg} \)

Legacy P
Incidental P

8 kg/ha/yr
1 kg/ha/yr
<1 kg/ha/yr

Buda et al., 2009 (J Environ Qual)
Legacy P in Streambanks

Iowa - nearly one third of total P loads

Contribution of streambanks to phosphorus export from Iowa


J. Soil and Water Conservation, 2022

11-143% of mean annual load
Snake River
Upper Mississippi
Western Lake Erie
Lake Champlain
Upper Chesapeake
Lower Chesapeake
Lower Mississippi

USDA Legacy P Project
CEAP Watersheds
USDA Legacy P Project

Watershed highlights

Dairy farms, irrigation return flows

Snake River

Streambank erosion, in-stream processes

Upper Miss. Le Sueur

Drainage management, sediment transport

Lower Miss. Big Sunflower

Tile drains, 4R fertilizer management

Western Lake Erie

Dairy farms, VSA hydrology, tile drains

Lake Champlain

Mixed livestock, in-stream process, VSA hydrology

Upper Chesapeake

Drainage ditches, riparian management, poultry farms

Lower Chesapeake
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*Scales of interpretation*

Field characterization and data analysis

Simulation modeling

Edge of field

Field, hillslope

Small watershed

Large watershed

Small watershed
USDA Legacy P Project

Legacy P assessment from long-term data

Long-term database

WRTDS and GAM analysis

Edge of field

Small watershed

CONCENTRATION/DISCHARGE AND MANAGEMENT RELATIONSHIPS

WRTDS (Weighted Regression on Time, Discharge and Season)

GAM (Generalized Additive Model)
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*Coordinated site characterization*

Locally-determined characterization strategies

Standard depths:
- 0-5 cm
- 5-10 cm
- 10-15 cm

Common hypothesis testing

Standard sample handling protocols for soils and sediments
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Examples of hypothesis-driven sampling

Sloping landscapes - hydrologically active areas

Flat landscapes – activation of legacy P with drainage

(a) Critical source areas (CSAs) of P loss

(b) Proposed transects for sampling CSAs

Map showing
- Critical source areas
- Proposed transects

Legend:
- Closed depression

Maps and images of landscapes and drainage systems.
Legacy P Management Recommendations

**Building upon existing conservation practices**

- **Avoid**
  - the **RIGHT SOURCE** of P applied
  - .. in the **RIGHT PLACE**
  - .. in the **RIGHT AMOUNT**
  - .. at the **RIGHT TIME**

- **Control**
  - Conservation tillage can reduce P loss in runoff
  - Cover crops can reduce P loss in runoff and increase infiltration

- **Trap**
  - Vegetative buffers can trap particulate P and take up some soluble P
  - Wetlands can trap particulate P and take up some soluble P
  - Wetlands and vegetative buffers can transition from being a sink to source of P to runoff
  - Treatment of wetlands and buffers with waste byproducts that can bind P may decrease P runoff

- Frequent soil and manure testing, subsurface injection, and avoiding application to areas prone to runoff and erosion, will maximize crop uptake while reducing runoff and leaching
Legacy P Avoidance Recommendations

Tackling the foundation of fertilizer management

“Build up and maintain” vs “Sufficiency”

http://www.soiltestfrst.org
Legacy P watershed modeling

Extrapolate management recommendations

Can local strategies impact regional outcomes?

P legacies - Time lags in recovery

- Return to baseline conditions widely variable - decades to millennia

- Sharples et al. 2013. J. Env. Qual. (review) (~50 yrs)
- McDowell et al. 2020. front. In Env. Sc. (~50 yrs)
- Chen et al. 2019. Biogeoch. (~500 yrs)
- Carpenter 2005. PNAS. (~1000 yrs)

How long to recovery?
USDA Legacy P Project

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✓ https://www.nrcresearchextension.com/detail/national/technical/nra/ceap/ws/?cid=nrcseprd1890821

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