Modeling the Impacts of Field Management Practices on Phosphorus Losses through Tile Drains

Vermont Agricultural Water Quality Partnership Confernece
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Overall Study Objectives

Calibrate and validate the APEX model for both surface transport and tile transport components of total phosphorus (P) in VT.

- Improve parameterization of APEX for use in Farm-PREP
- Increase the acceptability of the modeling approach

Evaluate the effects of conservation practices and innovative manure management technologies on P losses from surface and tile processes.

- Simulate selected field conservation practices (e.g., no till, cover cropping)
- Simulate innovative manure management technology (e.g., DAF, evaporation)
- Quantify P losses from selected sites, before and after conservation practice and manure technology implementation

Modeling Site Selection Summary

Selected surface edge-of-field and tile sites focused on the Stone NRCS/LCBP dataset, PLUS 1 site from Miner Institute.

Selected surface edge-of-field sites include:

- 3 continuous hay fields
- 1 continuous corn field
- 1 corn/fallow field

Selected tile drain sites include:

- 1 soy/corn field
- 3 continuous corn fields
- 1 continuous alfalfa field
- 1 hay/corn field

Surface edge-of-field plus tile drain site:

- Continuous corn

Site ID	Site Type	Current Crop or Rotation	Total years of monitoring data
SHE1 (Shelburne)	Surface	Continuous Hay	6.5
SHO1 (Shoreham)	Surface	Continuous Hay	3.5
FER1 (Ferrisburgh)	Surface	Continuous Hay	3.5
CHA1 (Charlotte)	Surface	Corn (2015-17); fallow (2018);	3.5
PAW1 (Pawlet)	Surface	Continuous Corn	3.5
JBT01	Tile	Soy/Corn	2
JBT04	Tile	Corn	1
JBT05	Tile	Corn	2
JBT07	Tile	Corn	2
JBT11	Tile	Alfalfa	2
JBT18	Tile	Hay/Corn	2
M1	Surface/Tile	Continuous Corn	4

APEX Model Background

Developed by USDA and Texas A&M University

- Farm/small watershed scale model
- Used in national Conservation Effects Assessment Project (CEAP)

Simulates:

- Water, sediment, nutrient, and pesticide transport from fields
- Crop growth, biomass, yields, carbon cycling

Agronomic management:

- Irrigation, drainage, furrow dikes
- Buffer strips, grass waterways, cover cropping
- Fertilizer and pesticide applications
- Manure management
- Crop rotations
- Conservation tillage

APEX Model Setup and Initial Parameterization

Initial model setup through Farm-PREP:
- Field boundaries
- Soils data extraction from SSURGO
- Average slopes from DEM

Weather data:
- Site specific for edge-of-field sites and Miner site in NY
- Combined site-specific and local NWS station from St. Albans for tile drain sites

Crop rotations, tillage practices, manure and fertilizer application rates:
- Based on best available farm records
- Some assumptions made on manure rates and nutrient contents for some tile sites

Tile drainage:
- Depth
- Network characteristics/approximate spacing

APEX Calibration and Validation Objectives

Develop a single APEX parameterization approach applicable to a wide range of VT field conditions:

- Crop rotations
- Agronomic practices
- Soils
- Tile drained and un-drained

Achieve unbiased and satisfactory model performance over the majority of sites and incorporate parameterization approach into APEX simulations in Farm-PREP.

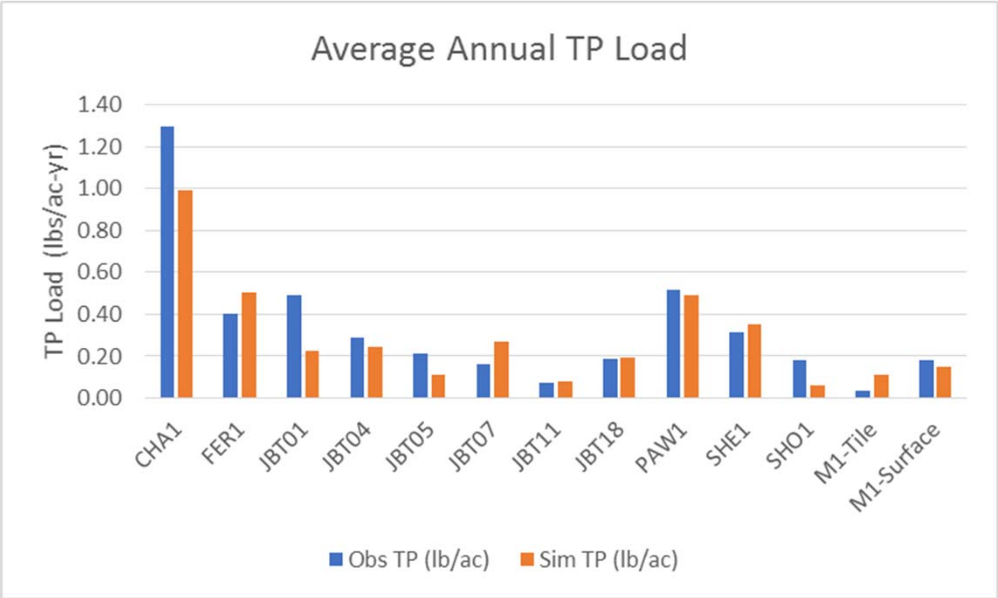
Assess robustness of the regional calibration and model prediction uncertainty through a probabilistic simulation approach (Monte Carlo analysis) that quantifies the effects of parameter uncertainty on model simulations.

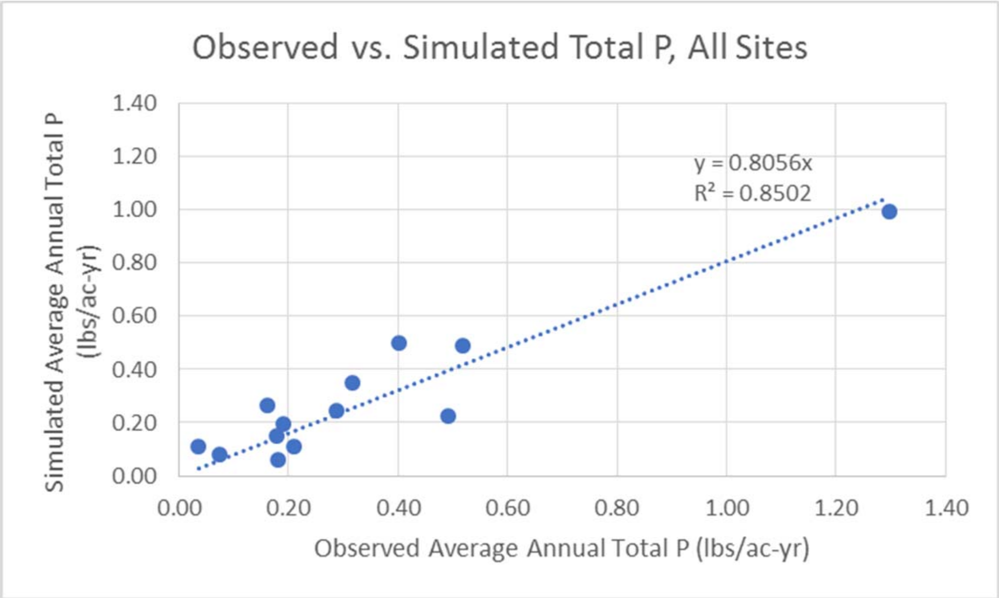
- Focus on soils data uncertainty
- Evaluate calibration improvements when soils characteristic variability is accounted for

APEX Calibration and Validation Results: Global Calibration, Representative Soil Parameters, All Sites Combined

Based on a single global parameter set for all 12 sites, and SSURGO representative (average) soil properties:

- Overall total P percent bias across all sites: -0.2%
- Average absolute error in total P across all sites: 0.16 lbs/ac-yr
- Model captures magnitude and variability across sites very well

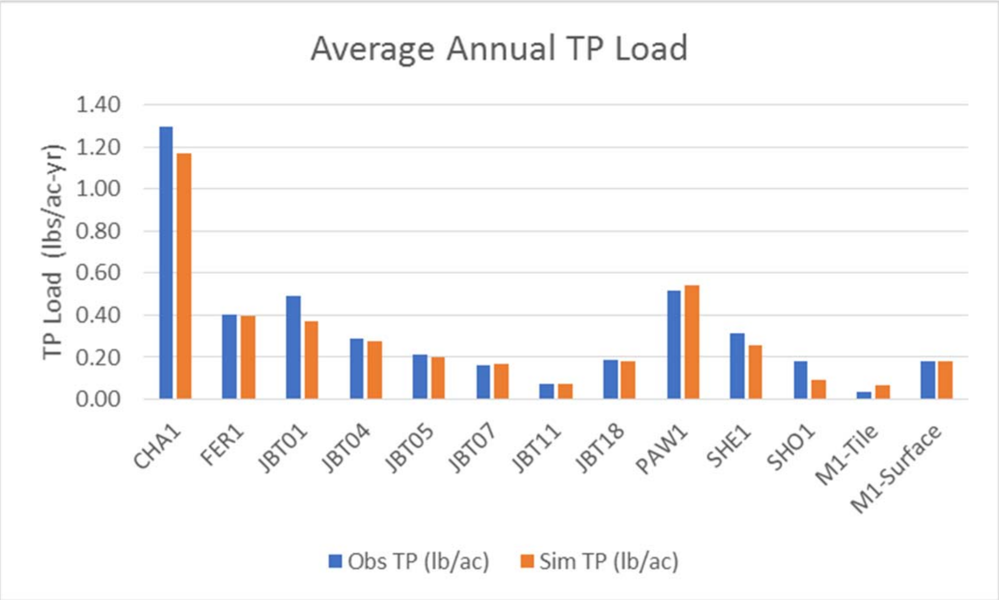


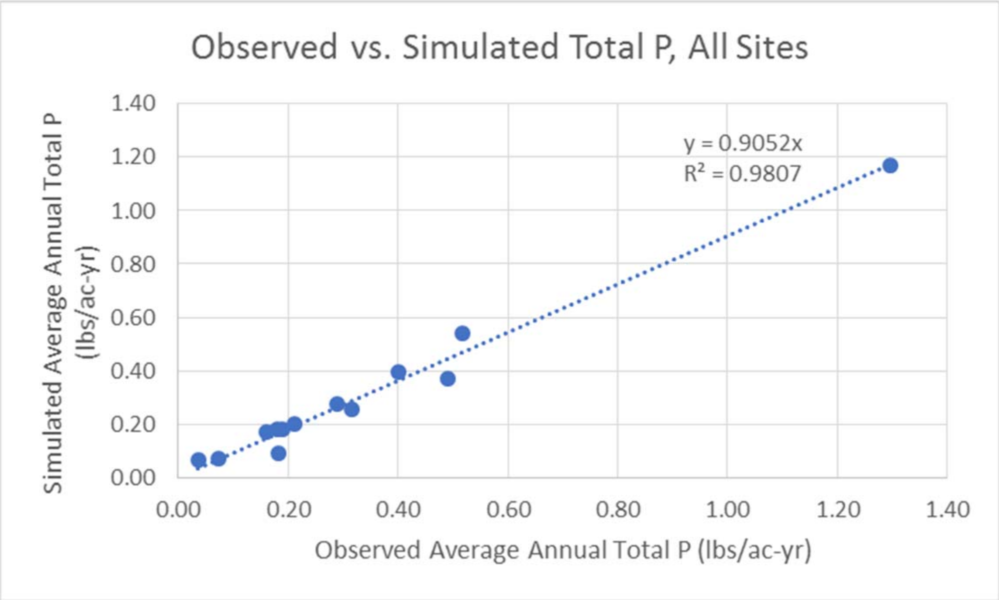


APEX Calibration and Validation Results: Global Calibration, “Best” Soils Parameters from Monte Carlo Analysis

At each site, the soil parameters from within the SSURGO range that minimized bias in average annual P loss were identified.

- Simulations at all sites improved
- Average absolute error in total P across all sites: 0.13 lbs/ac-yr
- R^2 of observed versus simulated average annual total P loss: 0.98





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Conservation Practice and Manure Management Scenario Modeling of Calibrated Sites

Five calibrated sites were selected for scenario modeling:

- Three tile sites from Jewett Brook
  - JBT01: Soy/Corn rotation, higher total P loss
  - JBT11: Continuous alfalfa, low total P loss
  - JBT18: Hay/Corn rotation, moderate total P loss
- One edge-of-field site
  - PAW1: Continuous Corn, moderate/high total P loss
- The tile/edge-of-field site from Miner
  - Low surface P loss
  - Low tile P loss

The global calibrations with “best” soils parameters were used for scenario modeling to examine:

- Impacts of field conservation practices on P losses
- Effects of innovative manure management technology on P losses

Conservation Practices and Manure Technology Selection for Scenario Modeling

Four field conservation practices were evaluated:

- Cover cropping
- No Till
- Manure injection
- Cover cropping + no till

Two manure technologies were evaluated:

- DAF
- Evaporation

Two soil P scenarios evaluated:

- Optimal P (5 ppm Modified Morgan’s)
- High P (8 ppm Modified Morgan’s)

Simulations quantified:

- Subsurface P loss
- Surface Soluble P losses
- Surface Sediment P losses
- Total P losses

Manure Technology Parameterizations

Primary benefits of implementing manure management technologies:

- Generation of new manure-based products that allow for placement where and when the nutrients are needed
- Capability to store and transport manure products (avoid application on already high P soils)

Manure technologies parameterized for 'optimal' P soil scenarios:

- Application timing of manure product applications was moved from 25% in spring/75% in fall for standard liquid manure to 100% of products and nutrients application in spring with the DAF and evaporation technologies
- Nutrient contents and application methods were modified for manure technology products

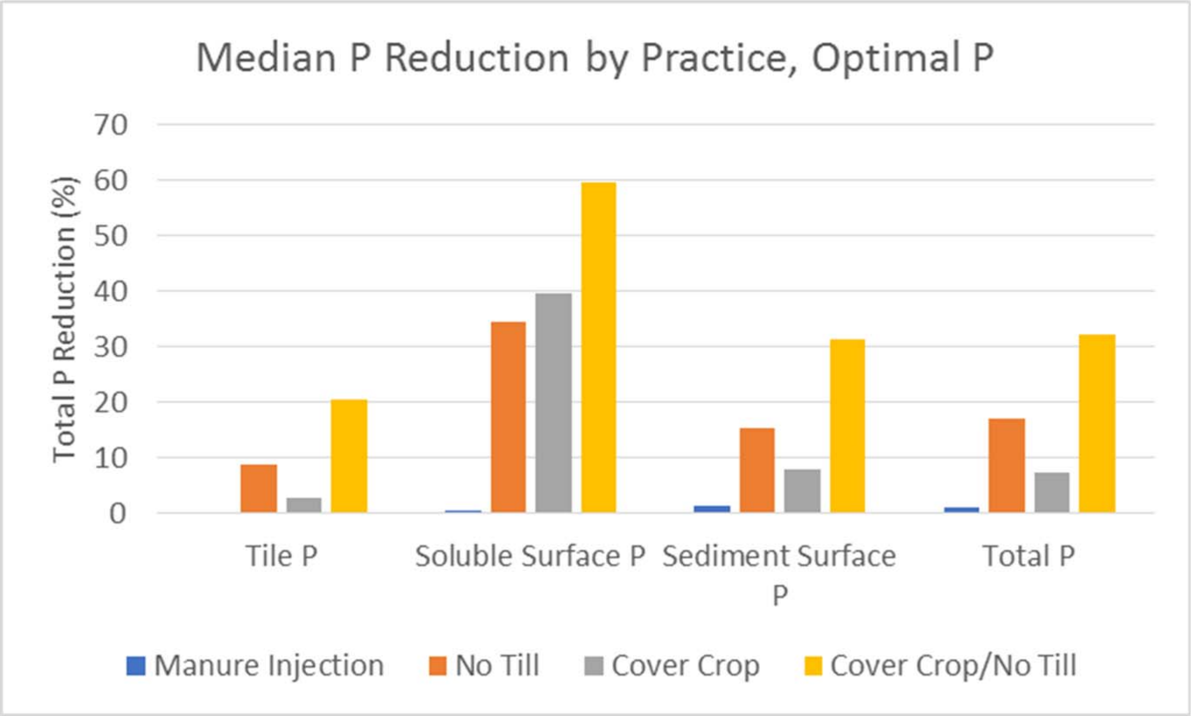
Manure technologies parameterized for 'high' P soil scenarios:

- Same assumptions as 'optimal' P scenarios for application timing, nutrient content and application methods
- Annual application rates of manure products can be reduced to meet crop demand
- Manure products stored in some years (i.e., not applied to example field) are assumed to be applied elsewhere on the farm to fields that have a greater need for additional P

Optimal P Soils Simulations, Conservation Practices

Conservation practices:

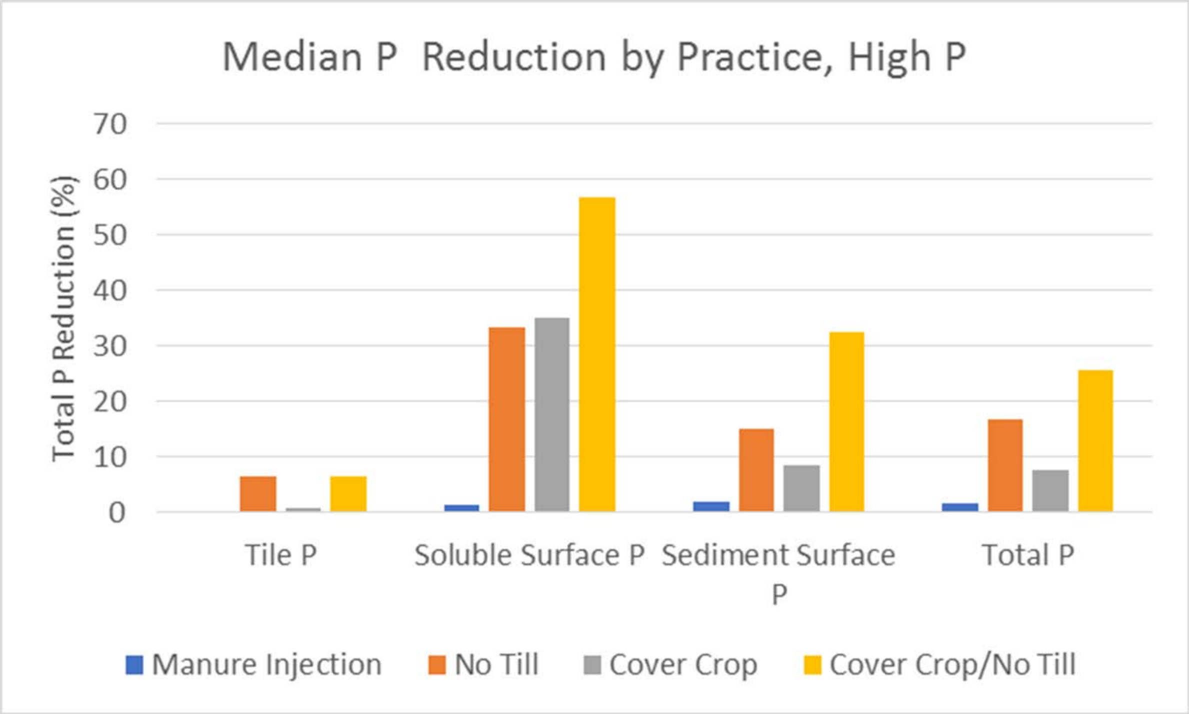
- Magnitude of P load components can vary, with sediment P generally highest, followed by tile P and soluble P
- Effectiveness of reduction were highest for soluble P and generally lowest for tile P
- Effectiveness of each conservation practice varied (e.g. cover cropping resulted in a sediment P reduction ranging from 1.6% to 22.4%)



High P Soils Simulations, Conservation Practices

Conservation practices:

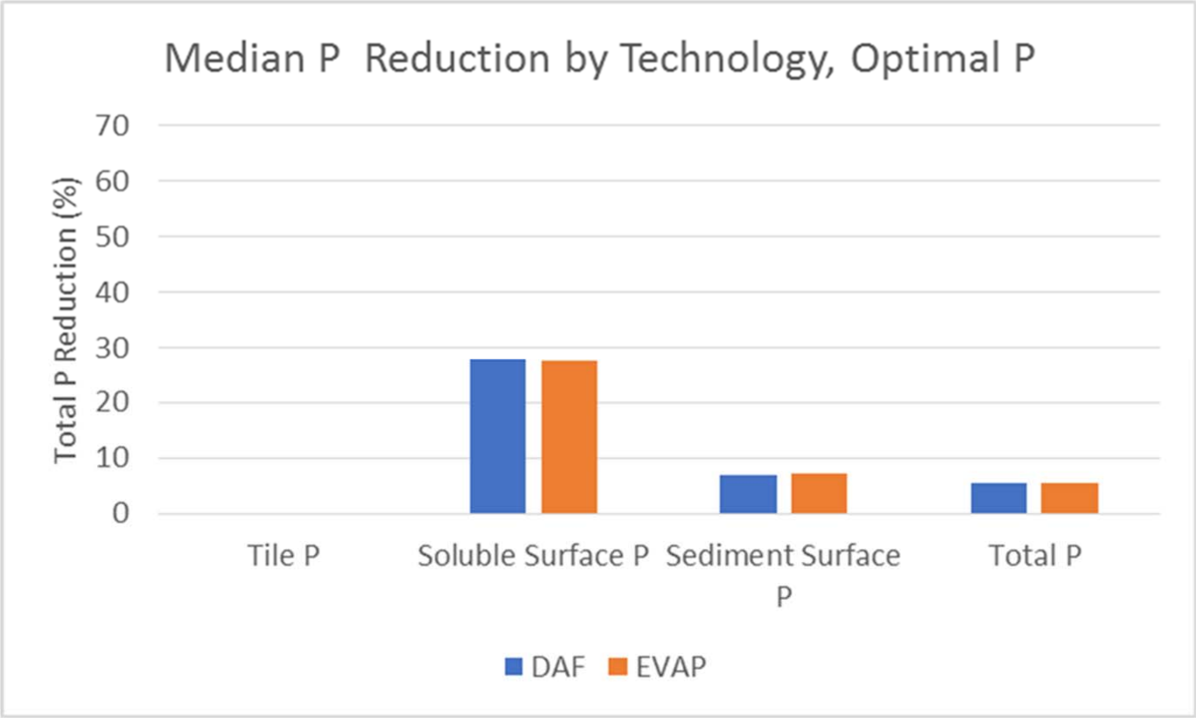
- Percent reductions in soluble P were greatest, followed by sediment and the tile P load
- Combination of cover crop and no till was the most effective at reducing P (median of 26%), followed by no till (median of 17%), cover crop on its own, and manure injection
- Compared to the ‘optimal P’ scenarios, the reductions in tile P losses were lower, likely due to the legacy P stored in the soils continuing to leach



Optimal P Soils Simulations, Manure Technologies

Manure technologies:

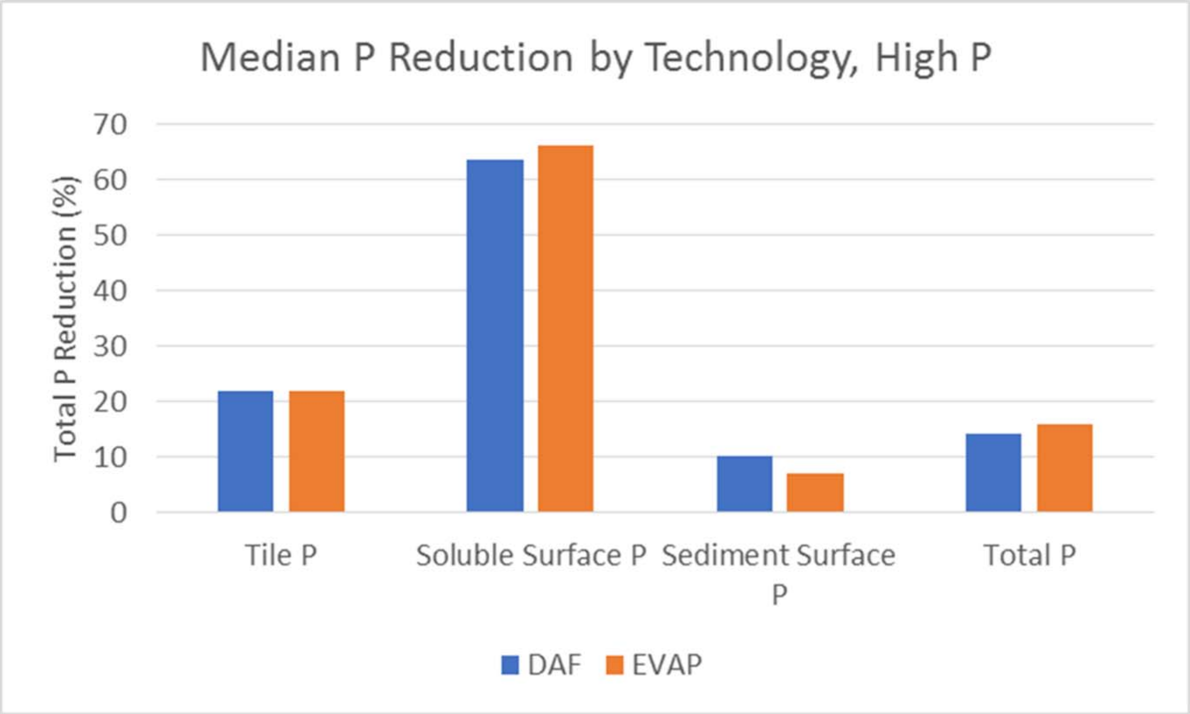
- Effectiveness of the two manure technologies on reducing P loads was similar
- P reduction effectiveness varied depending upon the P component, with percent reductions in soluble P most effective and tile P least effective
- Reductions in surface losses were largely driven by:
  - Change in application timing
  - Change in nutrient forms/application methods



High P Soils Simulations, Manure Technologies

Manure technologies:

- Highest percent reductions for soluble surface P, followed by tile P and sediment P
- Median total P reduction was ~15%, but ranged from a 6% increase to a 30% decrease
  - Scenarios where total P increased with manure technology were due to MORE manure-based P fertilizer applied to meet crop demand
- Tile P reductions were substantially higher than under the ‘optimal P’ conditions

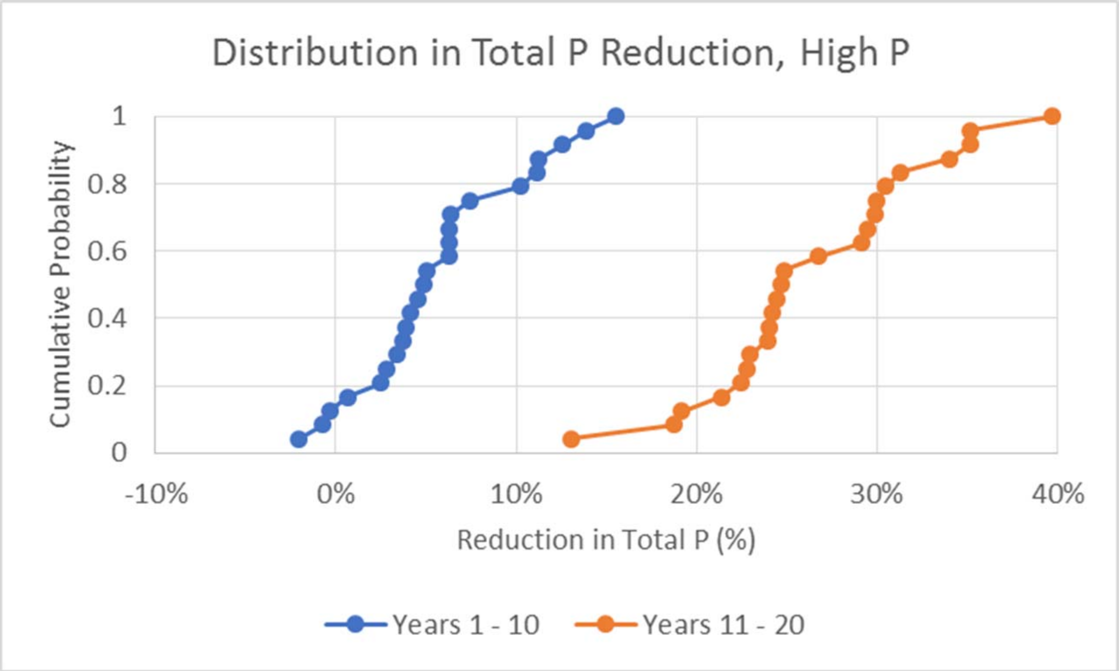


High P Soils, Differences in Early Years and Later Years Following Technology

In three sites where a more detailed analysis was conducted, reductions in average annual total P load are substantially greater for the years 11 – 20 than for years 1 – 10

Looking at each site independently, the greatest improvement from the second ten-year period compared to the first was observed at JBT01 followed JBT18 and M1

These reductions in the later 10-year period were largely driven by the drawdown of soil P over the first 10-year period



Conservation Practice/Manure Management Scenario Simulation Summary

Optimal P:

- Tile P losses:
  - Modest reductions with the implement of on-field conservation practices
  - Minimal responses to the adoption of manure technology
- Surface P losses (soluble and sediment):
  - Modest reductions with adoption of manure technology, degree of impact varied across conservation practices and sites
  - Generally, implementation of the conservation practices and manure technologies resulted in lower P loads

High P:

- A major benefit of manure management technology is the ability to reduce P inputs from manure and allow soils with excessive phosphorus to be drawn down
- Benefits of on-field conservation practices can be implemented in coordination with manure technology while maintaining the P load reduction effectiveness of those on-field practices

Thank you.

For more information

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