Reconciling Model Parameters for P with Field Measurements

Peter Vadas
USDA-ARS Dairy Forage Research Center
Original EPIC P Model Development


Common Soil P Routines

- **P Inputs**
  - Organic P
  - Active P
  - Stable P
  - Labile P

- **Runoff Dissolved P, P Leaching, Crop P Uptake**

- **Soil Total P for Sediment P Loss**

  - Make sure pool sizes are simulated well to feed pathways
    - Good initialization
    - Good dynamics as soil P changes though time
  - Make sure P loss is simulated well as a function of pool sizes
P Pool Initialization

- **Labile P**: Active P = PSP: (1-PSP)
- Stable P = 4 x Active P
- Organic P = OC / 14 / 8
- Sum of pools = soil Total P

- Need to estimate Labile P, PSP, check that sum of pools is good estimate of soil total P
Initializing Labile P

- Originally measured for EPIC with anion exchange membranes – represents P dissolved in solution and easily desorbed from soil
- AE-P typically less than common STP amounts, probably more variable
- Correlated to measured STP so it can be initialized from available data
- Original EPIC relationships different from later ones (underestimate labile P) – maybe due to data set with relatively low soil P
- Now, estimate labile P as 0.5 of Bray-1, Mehlich-3; equal to Olsen and Mehlich 1
- Be careful with high pH or calcareous soils with different chemistry
Initializing PSP

- Originally experimentally measured for EPIC
  - Measure labile P, incubate soil with added P for 6 months, re-measure labile P
  - PSP = % of added P that remains as labile P
- Correlate PSP to commonly measured soil properties (clay, OM, labile P)
- Measuring PSP introduces same variability as with measuring labile P as AE-P, same original data set
Testing P Initialization

• Do EPIC equations to estimate Labile P and PSP initialize P pools well enough so estimated total P correlates with measured total P?

• Estimate Labile P from STP
  • 0.5 x Mehlich 3 P, Bray 1 P
  • 1.0 x Olsen P, Mehlich 1 P

• Estimate PSP from soil properties (clay, OM, Labile P) from EPIC

• Estimate total P as sum of pools and compare with measured total P

Testing P Initialization

$y = 0.70x + 62.2$

$R^2 = 0.75$

$n = 480$

- Older versions of SWAT may not include Labile P with sum of pools, which will underestimate total P even more
- EPIC equations may estimate less Labile P from STP, resulting in even less total P
New equations for PSP

- Estimate Labile P from STP
  - $0.5 \times$ Mehlich 3 P, Bray 1 P
  - $1.0 \times$ Olsen P, Mehlich 1 P
- Use measured STP and total P to calculate PSP
  - Total $P = \text{Labile P} + 5(1 - \text{PSP} \times \text{Labile P})/(\text{PSP})$
- Relate calculated PSP (not measured) to soil properties (clay, OM, Labile P)
- Use soil properties, STP to estimate pools and total P as sum of pools, compare to measured total P

Testing new P Initialization

\[ y = 1.02x - 17.9 \]
\[ R^2 = 0.87 \]
Implications

- New approach estimates lower PSP from same soil properties, which means greater Active, Stable, Total P
- SWAT default of 0.4 for PSP may be much too high for many soils, resulting in too little Total P
- Too little Total P = underestimation of sediment P loss in erosion, having to unrealistically set parameters for calibration
- PSP needs to be dynamic in model (increases as labile P increases) so more P remains as Labile P as soil P increases

Soil P Dynamics Over Time

- As soil P changes (P additions, crop uptake, P loss), need to move P between pools to maintain correct amount so P availability is correct for new P loss or uptake.
- When Labile or Active P relatively too big, calculate imbalance and move 0.1 of imbalance per day – older versions of SWAT had errors in absence of 0.1 from Labile to Active.
- Similar process between Active and Stable P, coefficient of 0.0076.
Testing Soil P Dynamics

• How do we test reliability of P simulation?
  1. Changes in simulated Labile P and total P over time should correlate with measured changes in both (Labile P:STP relation maintained)
  2. Simulated P loss (dissolved P, sediment P) should correlate with measured P loss at field scale
• Use both tests to see if P routines are robust and reliable
Changes in Total P over time

Measured data from 9 studies monitoring changes in total P from 4 to 25 years

Changes in STP over time

Measured data from 20 studies monitoring changes in soil P from 1 to 25 years

\[ y = 1.04x - 0.92 \]
\[ R^2 = 0.93 \]
\[ n=664 \]


Dissolved P loss in Runoff

Runoff Dissolved P

- Organic P
- Labile P
- Active P
- Stable P

Dissolved runoff P = Labile P \times \text{Runoff} \times Kd

Sediment runoff P = Total P \times \text{erosion} \times ER

Estimating Dissolved P Loss

\[ y = 0.002x + 0.05 \]

\[ R^2 = 0.73 \]

Similar to SWAT default of 175 for \( K_d \)

Estimating Total P Loss

Measured data from 28 studies from 13 different states, Australia, Ireland

\[ y = 1.03 \times 0.03 \]

\[ r^2 = 0.85 \]

Implications

• With PSP, Labile P estimated well, and dynamic PSP, EPIC equations for soil P dynamics, P loss are robust and reliable
  
  • In older versions of SWAT, no 0.1 factor when moving P from Labile to Active P. Result is that all added inorganic P moved immediately to Active P and slowly moves back to Labile P. This is opposite to what really happens and will underestimate dissolved P loss, especially for surface application.
  
  • Dynamics coefficients instead of 0.1 are an option too, with somewhat improved simulations

Logic of Soil P Routines

- Initialize Labile P from measured STP
- Initialize PSP from measured soil properties (OM, clay, Labile P)
- Initialize Organic P from measured OM
- Model uses PSP to initialize Active and Stable P, estimates Total P as sum of pools
- Model tracks changes in pool sizes over time based on PSP, imbalance coefficients
- Model estimates P loss based on Labile P and total P
- Use multiple tests for P simulation – STP and total P dynamics, dissolved and sediment P loss, P leaching, crop P uptake
Dissolved P Loss from Surface Manure, Fertilizer

- P into soil from tillage, liquid manure infiltration

\[ \text{Available P on Surface} \times \text{Availability factor} \times \frac{\text{Runoff}}{\text{Precip.}} \times \text{Distribution Factor} \]

All P not lost in runoff goes into soil, track changes in available surface P through time


Questions??