Reconciling Model Parameters for P with Field Measurements

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Original EPIC P Model Development

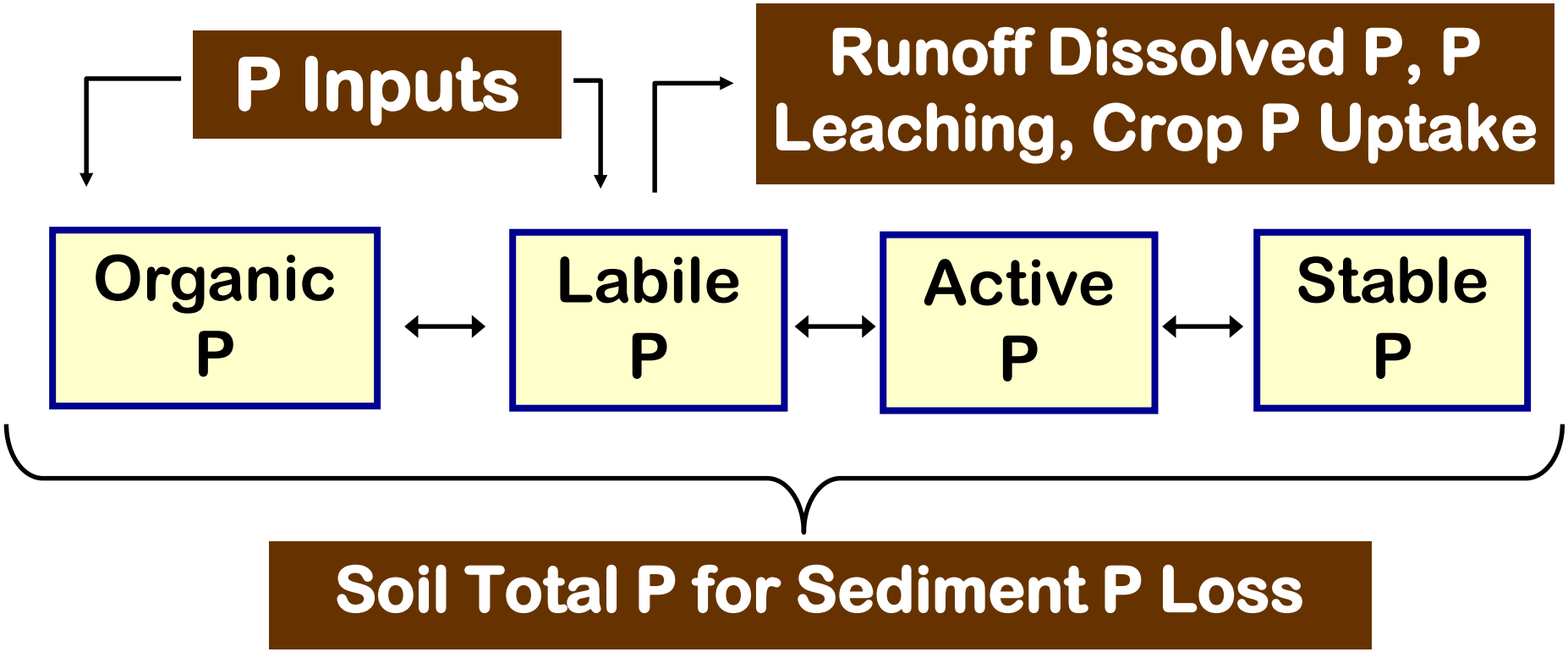
- Jones, C.A., C.V. Cole, A.N. Sharpley, and J.R. Williams. 1984. A Simplified Soil and Plant Phosphorus Model .1. Documentation. Soil Sci. Soc. Am. J. 48: 800-805.

- Sharpley, A.N., C.A. Jones, C. Gray, and C.V. Cole. 1984. A Simplified Soil and Plant Phosphorus Model .2. Prediction of Labile, Organic, and Sorbed Phosphorus. Soil Sci. Soc. Am. J. 48: 805-809.

- Jones, C. A., A. N. Sharpley, and J. R. Williams. 1984. A simplified soil and plant phosphorus model: III. Testing. Soil Sci. Soc. Am. J. 48:810-813.

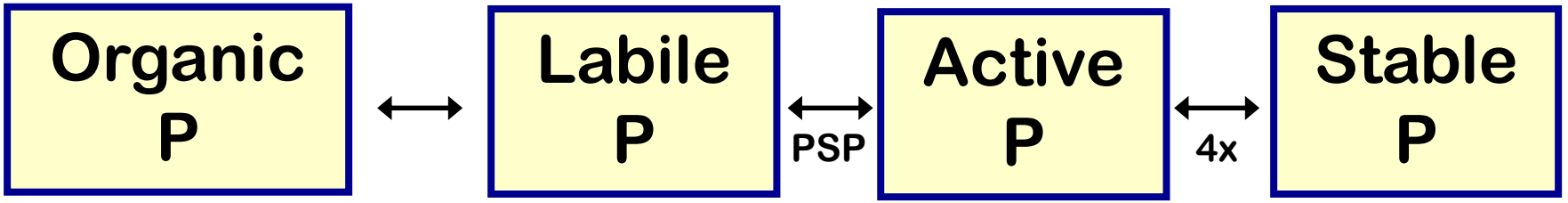
- Sharpley, A. N., U. Singh, G. Uehara, and J. Kimble. 1989. Modeling Soil and Plant Phosphorus Dynamics in Calcareous and Highly Weathered Soils. Soil Sci. Soc. Am. J. 53:153-158.

Common Soil P Routines



- 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

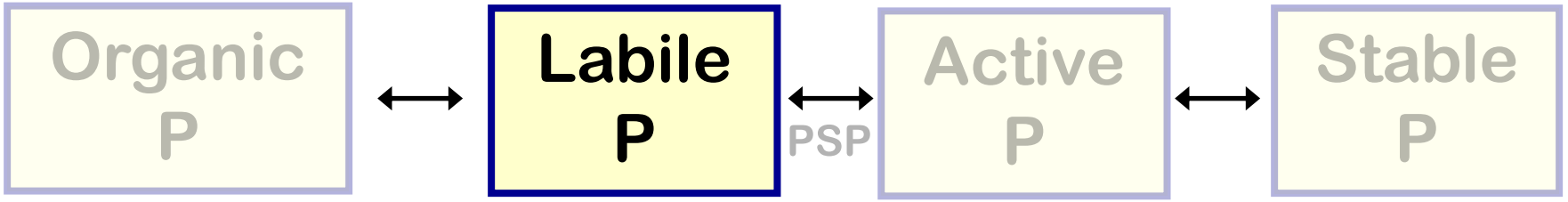
P Pool Initialization



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

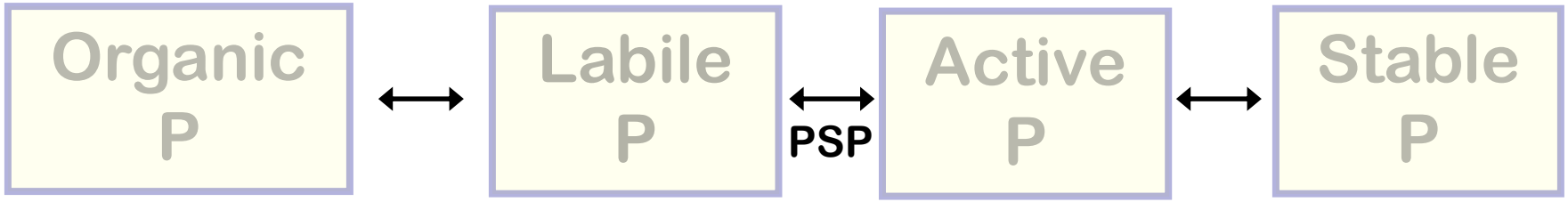
- Need to estimate Labile P, PSP, check that sum of pools is good estimate of soil total P

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

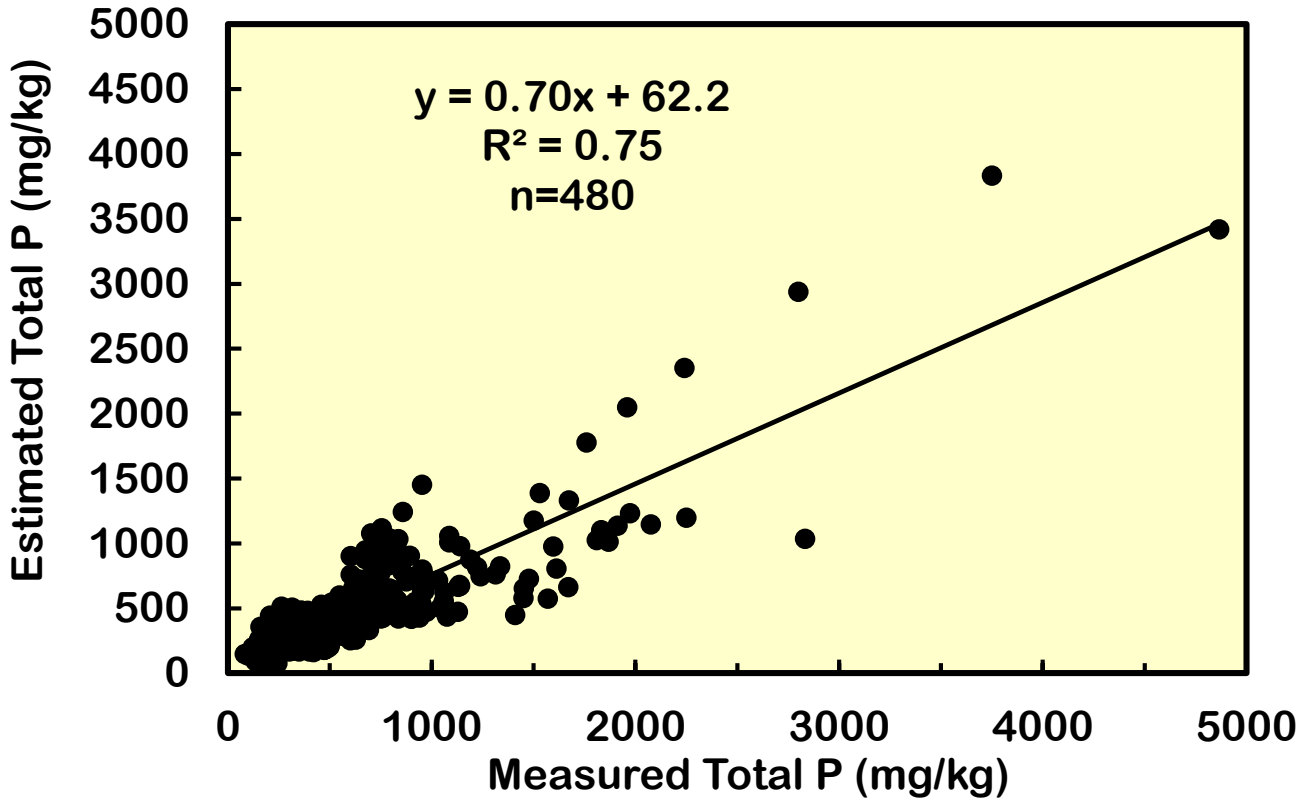
Testing P Initialization

- 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

Vadas, P.A., and M.J. White. 2010. Validating soil phosphorus routines in the SWAT Model. Trans. ASABE. 53:1469-1476.

Testing P Initialization



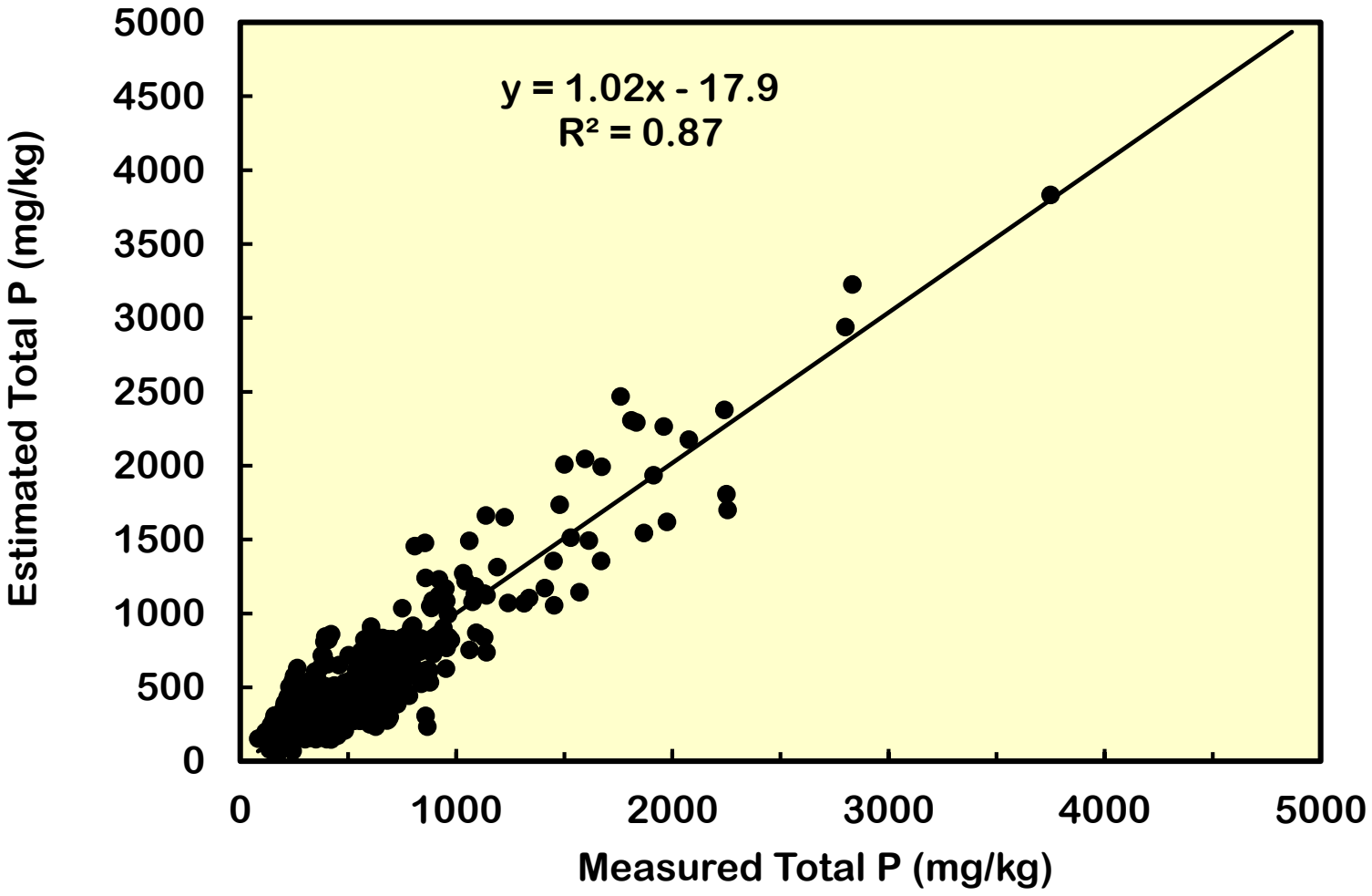
- Older versions of SWAT may not include Labile P with sum of pools, which will underestimate total P even more
- EPIC equations may estimate less Labile P from STP, resulting in even less total P

New equations for PSP

- Estimate Labile P from STP
  - 0.5 x Mehlich 3 P, Bray 1 P
  - 1.0 x Olsen P, Mehlich 1 P
- Use measured STP and total P to calculate PSP
  - Total P = Labile P + 5(1-PSP x Labile P)/(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

Vadas, P.A., and M.J. White. 2010. Validating soil phosphorus routines in the SWAT Model. Trans. ASABE. 53:1469-1476.

Testing new P Initialization

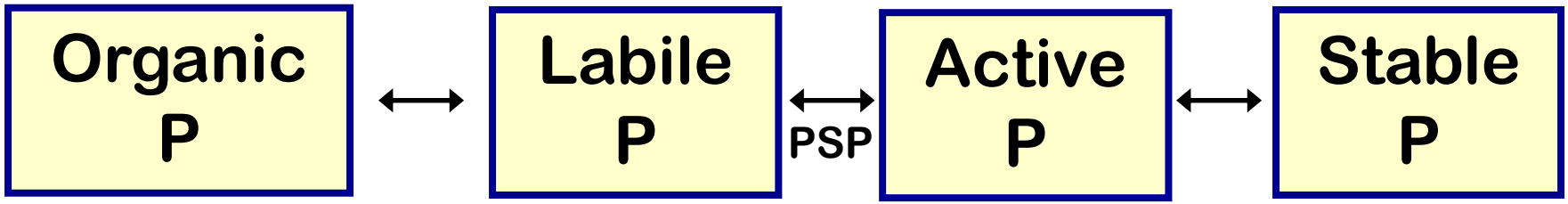


Implications

- 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

Bolster, C.H., and P.A. Vadas. 2018. Comparison of two methods for calculating the P sorption capacity parameter in soils. Soil Sci. Soc. Am. J. 82:493-501.

Soil P Dynamics Over Time



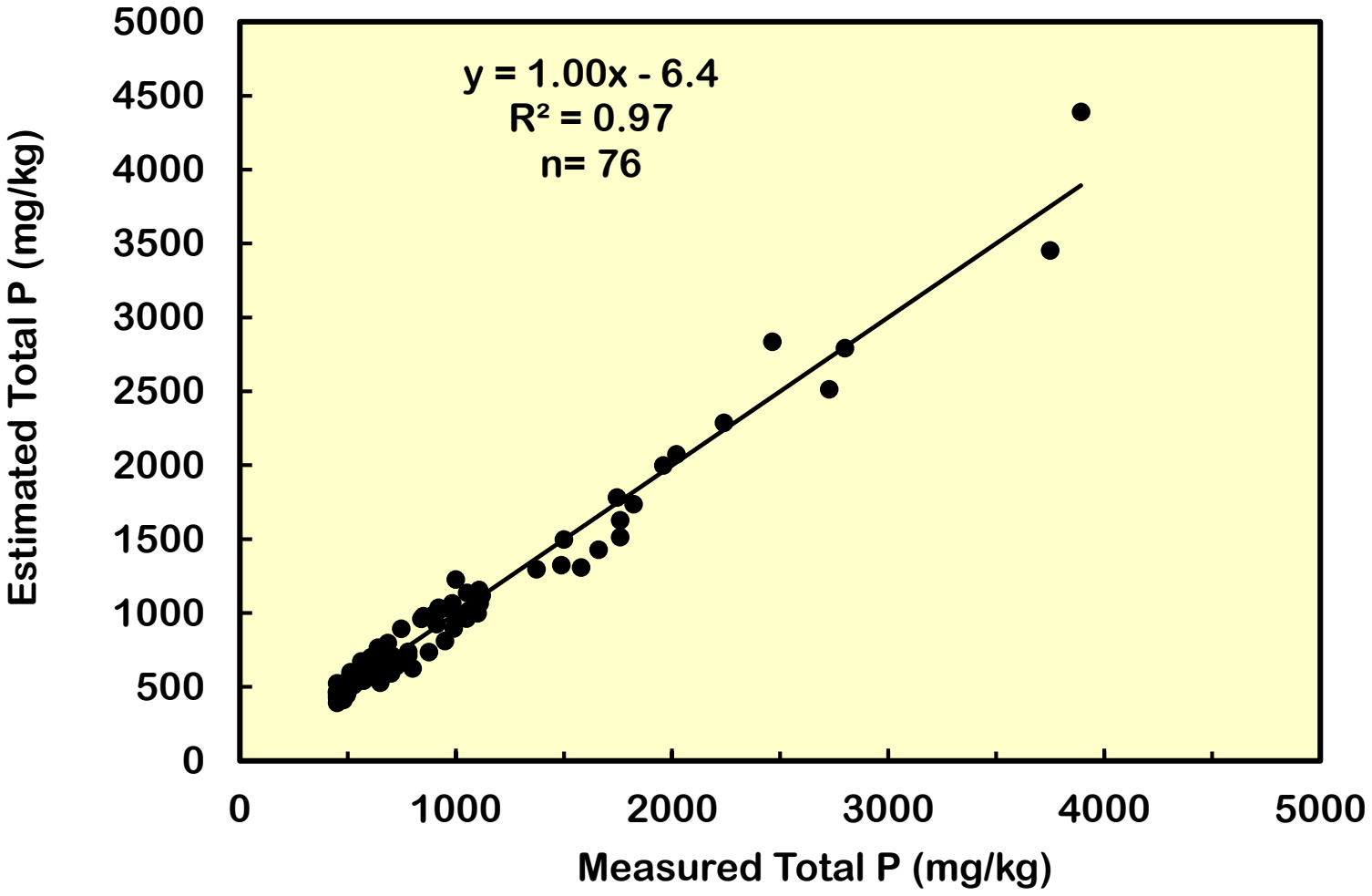
- As soil P changes (P additions, crop uptake, P loss), need to move P between pools to maintain correct amount so P availability is correct for new P loss or uptake
- When Labile or Active P relatively too big, calculate imbalance and move 0.1 of imbalance per day – older versions of SWAT had errors 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

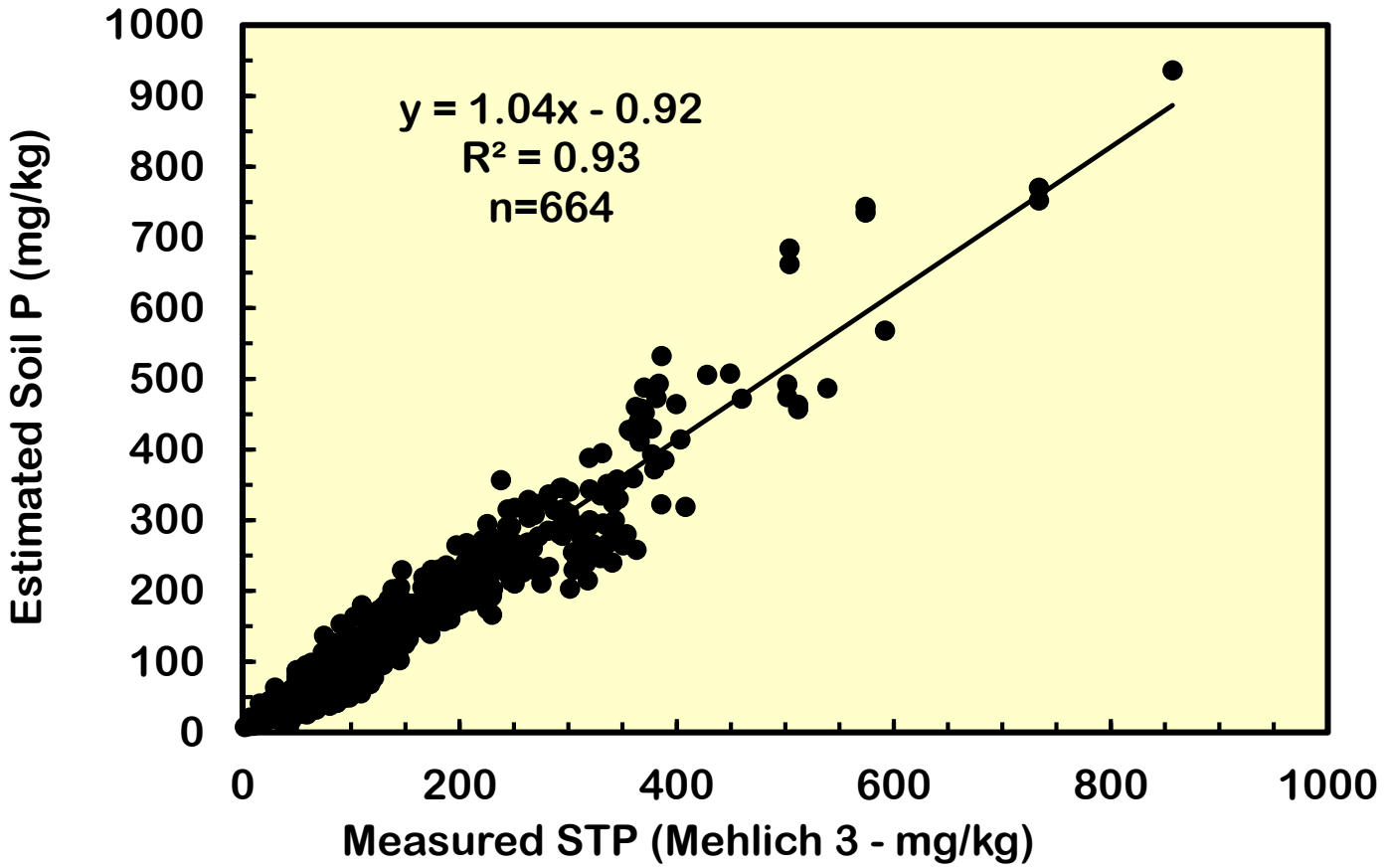
Measured data from 9 studies monitoring changes in total P from 4 to 25 years



Vadas, P.A., B.C. Joern, and P.A. Moore, Jr. 2012. Simulating soil phosphorus dynamics for a phosphorus loss quantification tool. J. Environ. Qual. 41:1750-1757.

Changes in STP over time

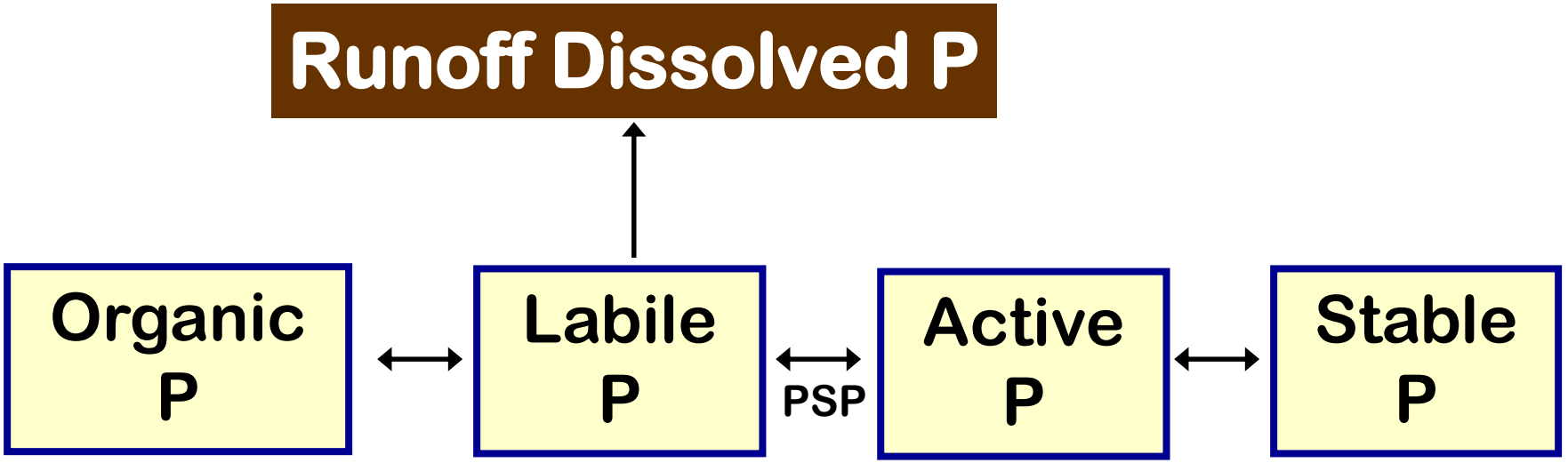
Measured data from 20 studies monitoring changes in soil P from 1 to 25 years



Vadas, P.A., B.C. Joern, and P.A. Moore, Jr. 2012. Simulating soil phosphorus dynamics for a phosphorus loss quantification tool. J. Environ. Qual. 41:1750-1757.

Vadas, P.A., N.M. Fiorellino, F.J. Coale, R. Kratochvil, A.S. Mulkey, and J.M. McGrath. 2018. Estimating legacy soil phosphorus impacts on phosphorus loss in the Chesapeake Bay watershed. J. Environ. Qual. 47:480-486.

Dissolved P loss in Runoff

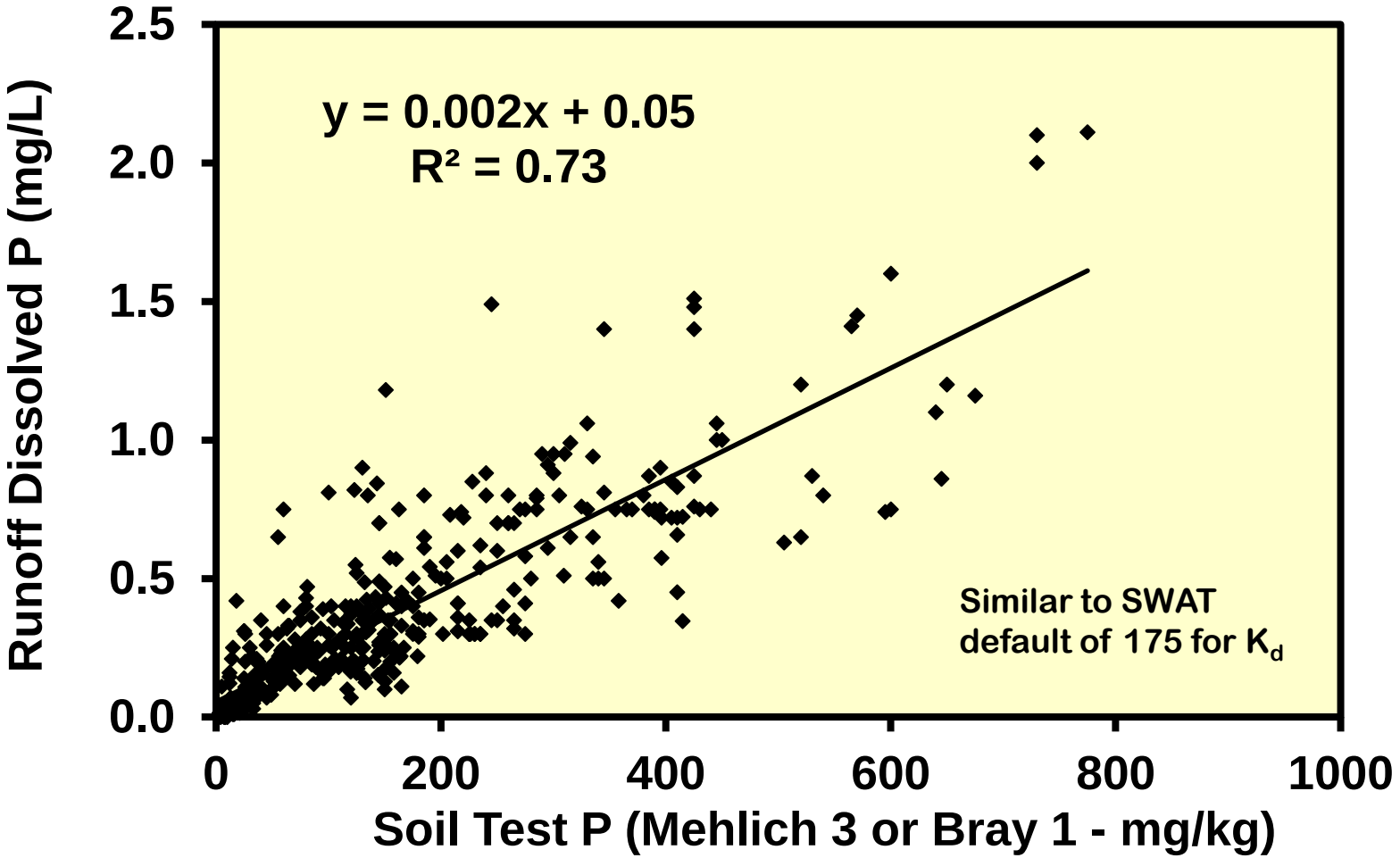


Dissolved runoff P = Labile P x Runoff x Kd

Sediment runoff P = Total P x erosion x ER

Menzel et al. (1980) Sharpley (1980)

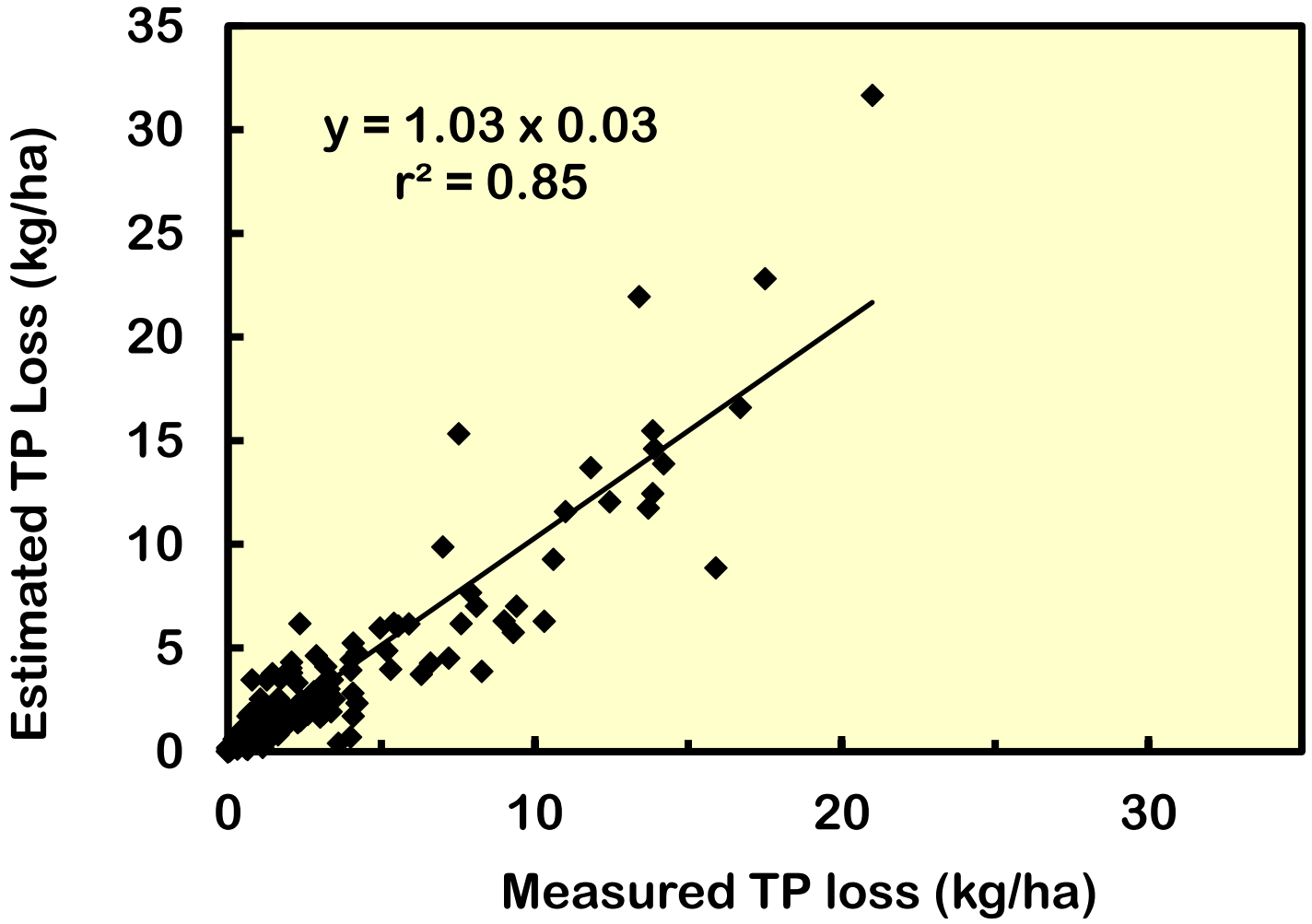
Estimating Dissolved P Loss



Vadas, P.A., P.J.A. Kleinman, and A.N. Sharpley. 2005. Relating soil phosphorus to dissolved phosphorus in runoff: A single extraction coefficient for water quality modeling. J. Environ. Qual. 34:572-580.

Estimating Total P Loss

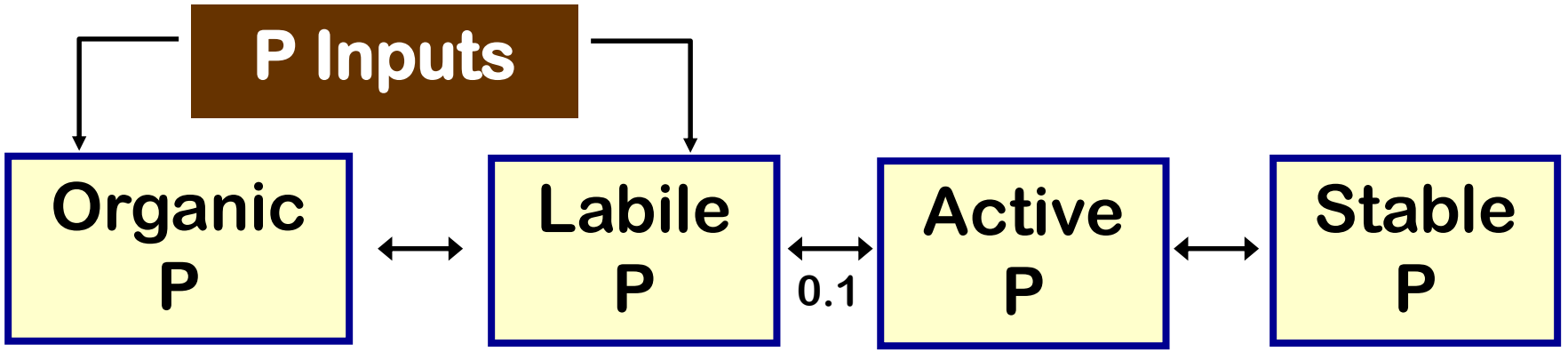
Measured data from 28 studies from 13 different states, Australia, Ireland



Vadas, P.A., L.W. Good, P.A. Moore Jr., and N. Widman. 2009. Estimating phosphorus loss in runoff from manure and fertilizer for a phosphorus loss quantification tool. J. Environ. Qual. 38:1645-1653.

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



Vadas, P.A., T. Krogstad, and A.N. Sharpley. 2006. Modeling phosphorus transfer between labile and non-labile soil pools: updating the EPIC model. Soil Sci. Soc. Am. J. 70:736-743.

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 applied

↓

P on surface

↓

Available P on Surface

↓

Dissolved P in Runoff

- P into soil from tillage, liquid manure infiltration

X Availability factor

Fertilizer: 100%
Manure: % WEP

$$X \frac{\text{Runoff}}{\text{Precip.}} X \text{ Distribution Factor}$$

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

Collick A.S., T.L. Veith, D.R. Fuka, P.J.A. Kleinman, A.R. Buda, J.L. Weld, R.B. Bryant, P.A. Vadas, M.J. White, R.D. Harmel, and Z.M. Easton. 2016. Improved Simulation of Edaphic and Manure Phosphorus Loss in SWAT. J. Environ. Qual. 45:1215-1225.

Vadas, P.A., W.J. Gburek, A.N. Sharpley, P.J.A. Kleinman, P.A. Moore, Jr., M.L. Cabrera, and R.D. Harmel. 2007. A model for phosphorus transformation and runoff loss for surface-applied manures. J. Environ. Qual. 36:324–332.

Vadas, P.A., L. Owens, and A.N. Sharpley. 2008. An empirical model for dissolved phosphorus in runoff from surface-applied fertilizers. Agric. Ecosys. Environ. 127:59-65.

Questions??