# Modeling soil P

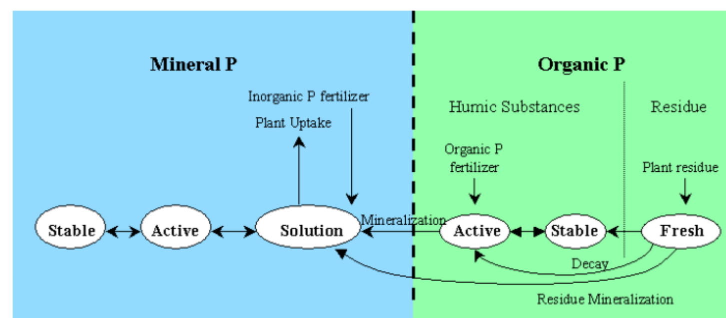
## Case study focusing on the Soil and Water Assessment Tool (SWAT) and ongoing research

Margaret Kalcic, Grey Evenson, Rebecca Muenich

Phosphorus Field to Watershed Modeling Workshop, August 23, 2018

# Outline - questions

1. ***Why do we care?***
2. ***Why use SWAT?***
3. ***Can SWAT simulate field-scale crop management?***
4. ***Can soil test phosphorus be input in SWAT?***
5. ***What other challenges (and opportunities) are we thinking about?***



# *Why do we care?*

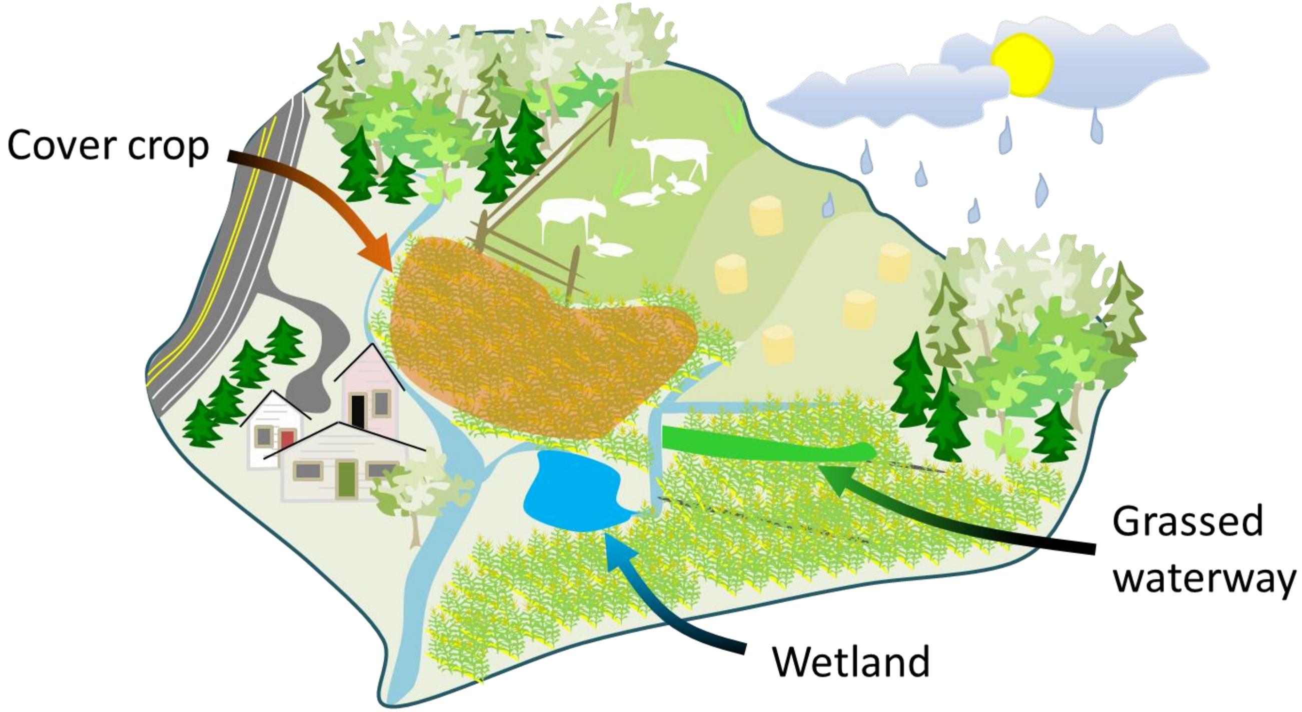
- We have used SWAT for many stakeholder-driven projects in the western Lake Erie watersheds. Stakeholder concerns/needs are consistent:
  - Input soil test P into SWAT
  - Use soil test P in scenario analysis
  - Better simulation of manure, which includes legacy P

- We have had concerns about the model:
  - Needed to reduce labile P to very low values for
    (a) calibration of reach-level P loading and
    (b) crop growth sensitivity to P fertilizers applied (Kalcic et al., 2016; Muenich et al., 2016)

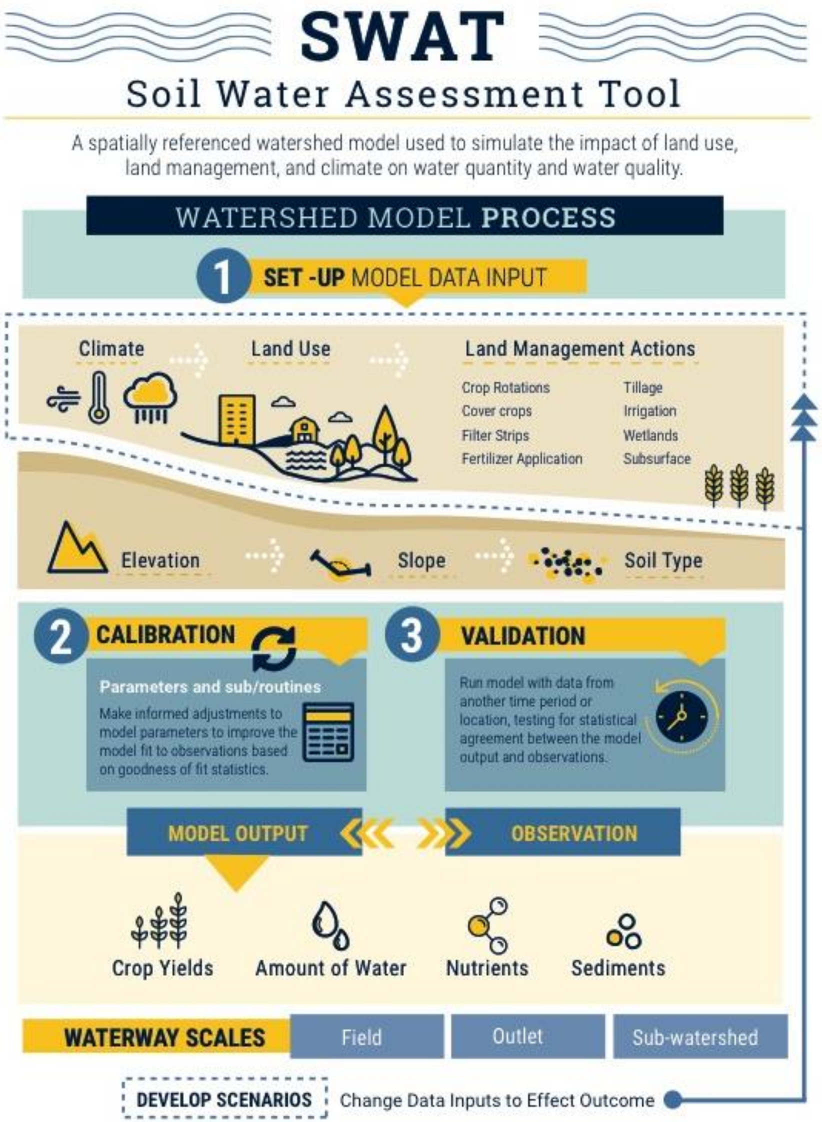
SWAT Soil & Water Assessment Tool

# ***Why use SWAT?***

- Estimate discharge, nutrients, sediments
- Evaluate impacts of farm conservation at watershed scale
- Test land use and cropping changes
- Other practical reasons including open source code, ARS support…



# SWAT is a complicated model with many decisions, inputs, and parameters




**Spatial discretization** *in initial model setup*

**Sub-model algorithms** *chosen*

**Inputs** *including sources, spatial resolution, and preprocessing of data*

**Land management** *includes assumptions based on disparate sources*

**Parameterization** *in choosing values to calibrate the model*

**Measured data** *used for calibration*

# Example: Multi-SWAT comparison in the Maumee

**WATER CENTER**
UNIVERSITY OF MICHIGAN

**APRIL 2016 UPDATE:** See inside front cover for updat

## Informing Lake Erie Agriculture Nutrient Management via Scenario Evaluation

UNIVERSITY OF MICHIGAN, ANN ARBOR

DONALD SCAVIA, MARGARET KALCIC, REBECCA LOGSDON MUENICH, NOEL ALOYSIUS, CHELSIE BOLES, REMEGIO CONFESOR, JOSEPH DEPINTO, MARIE GILDOW, JAY MARTIN, JENNIFER READ, TODD REDDER, DALE ROBERTSON, SCOTT SOWA, YU-CHEN WANG AND HAW YEN

RESEARCH COMMUNICATIONS RESEARCH COMMUNICATIONS

## Multiple models guide strategies for agricultural nutrient reductions

Donald Scavia[1*], Margaret Kalcic[1,2], Rebecca Logsdon Muenich[1], Jennifer Read[1], Noel Aloysius[2], Isabella Bertani[1], Chelsie Boles[3], Remegio Confesor[4], Joseph DePinto[3], Marie Gildow[2], Jay Martin[2,8], Todd Redder[3], Dale Robertson[5], Scott Sowa[6], Yu-Chen Wang[1], and Haw Yen[7]

In response to degraded water quality, federal policy makers in the US and Canada called for a 40% reduction in phosphorus (P) loads to Lake Erie, and state and provincial policy makers in the Great Lakes region set a load-reduction target for the year 2025. Here, we configured five separate SWAT (US Department of Agriculture's Soil and Water Assessment Tool) models to assess load reduction strategies for the agriculturally dominated Maumee River watershed, the largest P source contributing to toxic algal blooms in Lake Erie. Although several potential pathways may achieve the target loads, our results show that any successful pathway will require large-scale implementation of multiple practices. For example, one successful pathway involved targeting 50% of row cropland that has the highest P loss in the watershed with a combination of three practices: subsurface application of P fertilizers, planting cereal rye as a winter cover crop, and installing buffer strips. Achieving these levels of implementation will require local, state/provincial, and federal agencies to collaborate with the private sector to set shared implementation goals and to demand innovation and honest assessments of water quality-related programs, policies, and partnerships.

*Front Ecol Environ* 2017; 15(3): 126–132, doi:10.1002/fee.1472

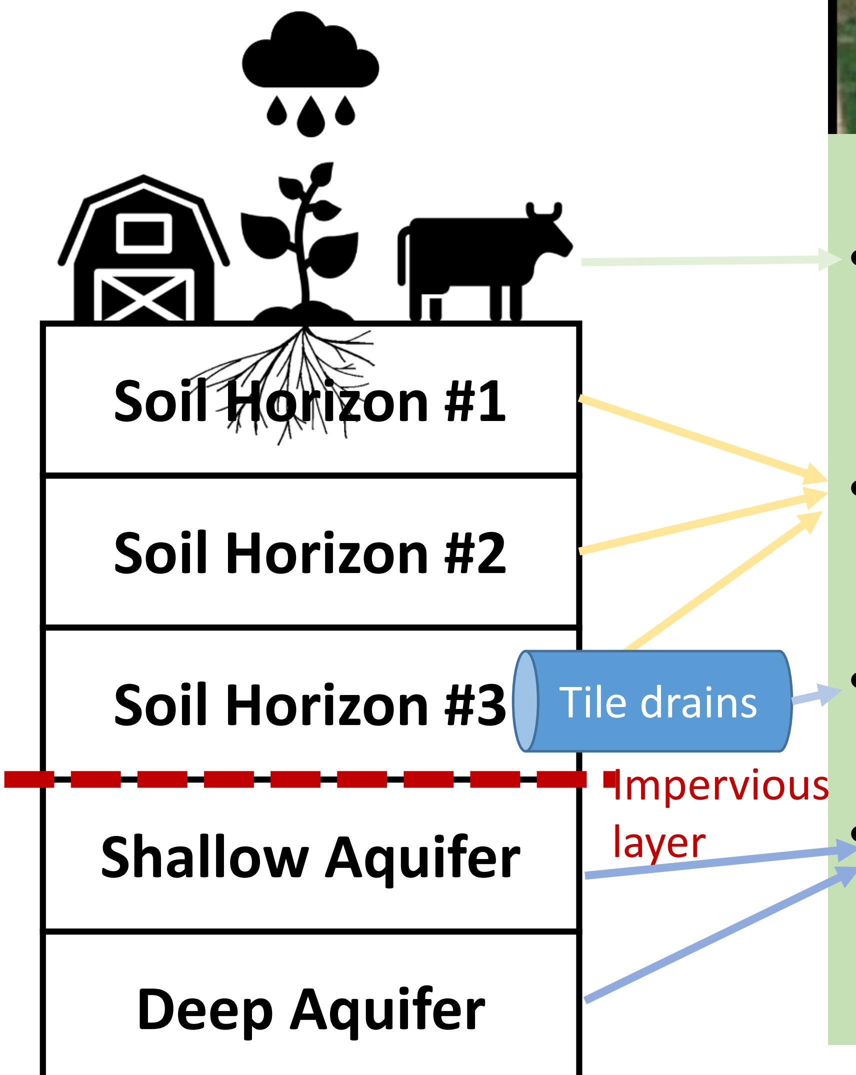
**Led** by Don Scavia at the University of Michigan (2015-2016)
**Funded** by the Erb Family Foundation
**Published** in Frontiers in Ecology and the Environment
Continued in project led by Margaret Kalcic and Jay Martin (2016-2018), funded by the Ohio Dept. of Higher Ed.

# *Can SWAT simulate field-scale crop management?*

Yes, if intentionally set up to do so

- Spatial unit: Hydrologic response unit (HRU)
- *Our model's* HRUs approximate farm-field resolution

# The hydrologic response unit (HRU)

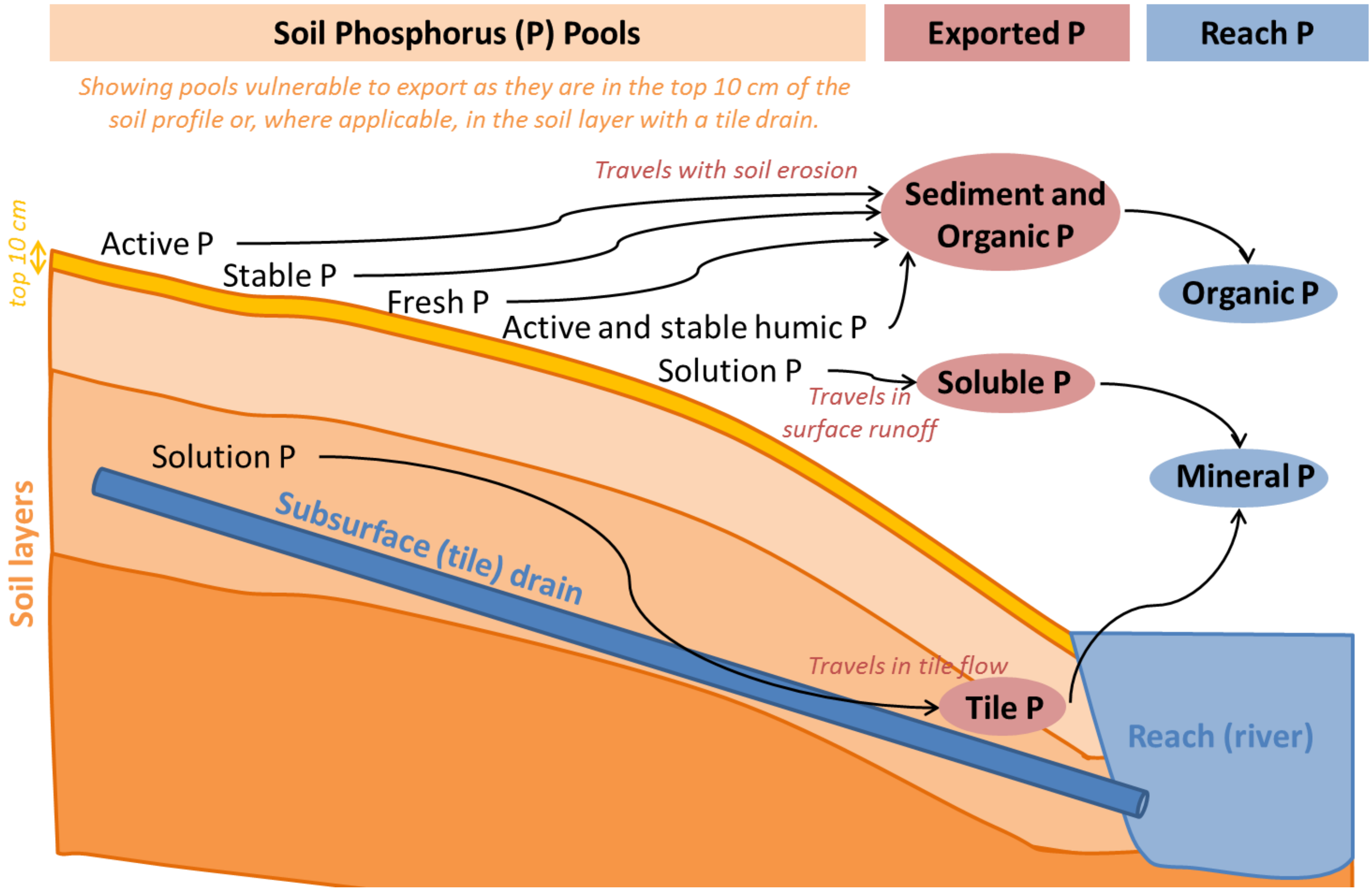



## HRU conceptual model

- Land cover and crop rotations defined via NASS Cropland Data Layer
- Soil horizons from SSURGO soil data (Inputs include depth, labile P, texture, $k_{sat}$, organic carbon, bulk density, AWC…)
- Tile drains placed according to soil drainage class
- Shallow and deep aquifers beneath soil profile

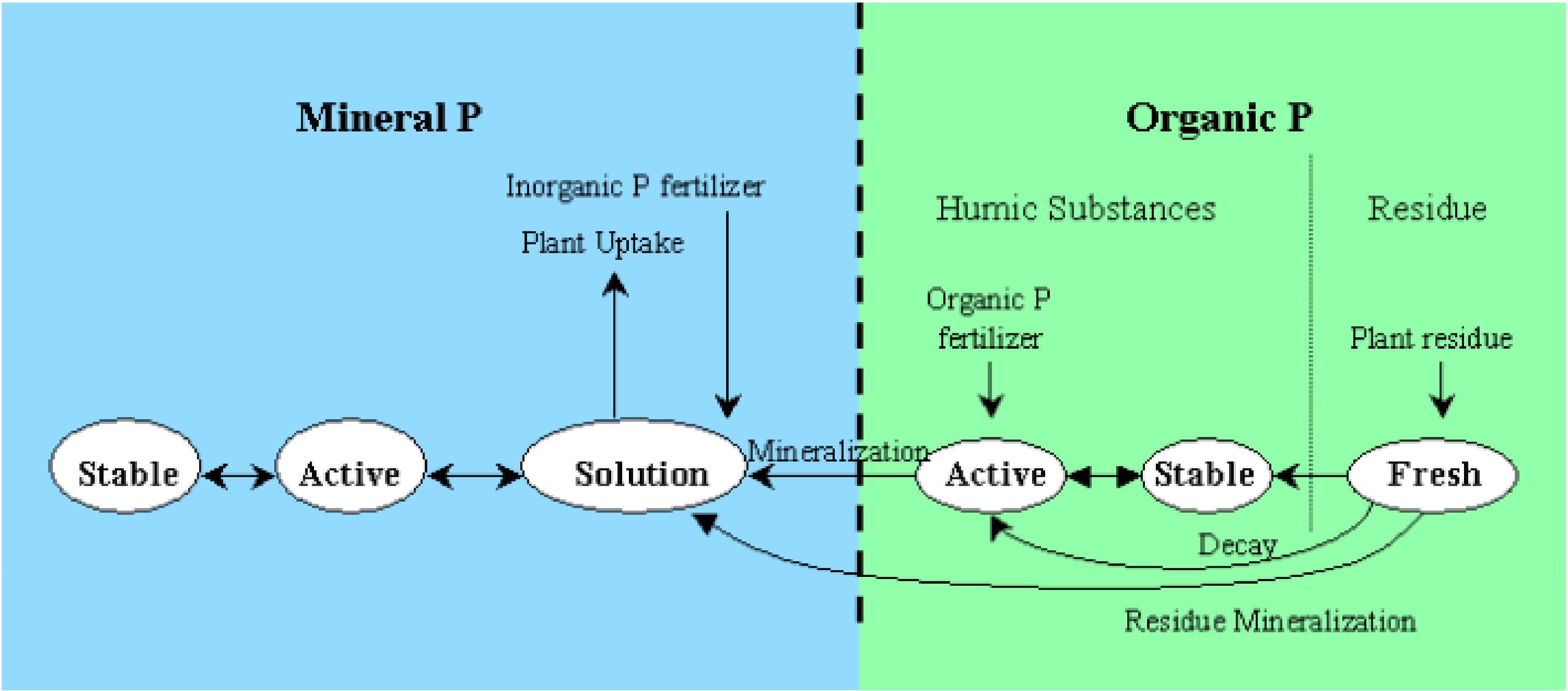
# *Can soil test phosphorus be input in SWAT?*

Let's start with P simulation from HRU to reach

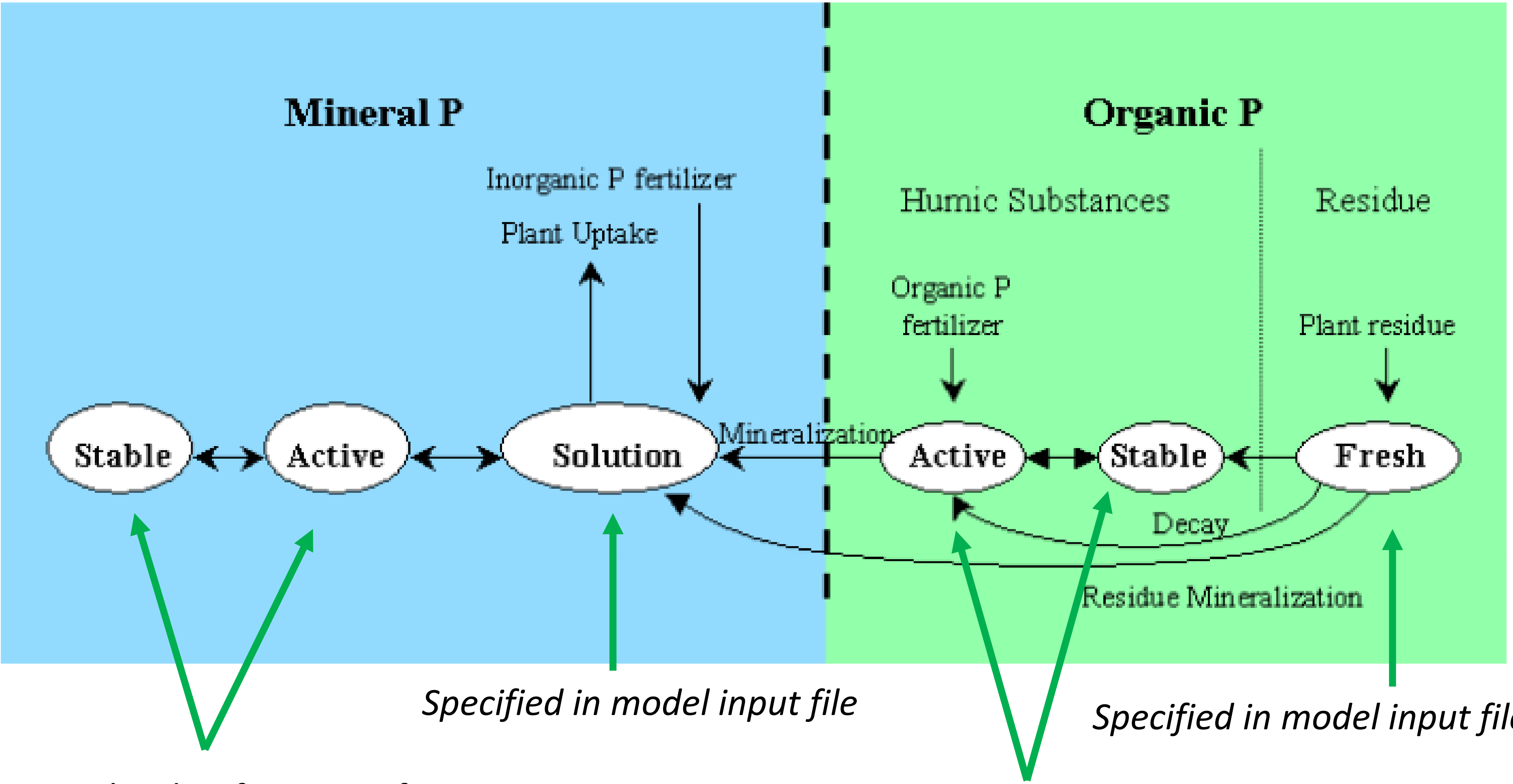


***Can soil test phosphorus be input in SWAT?***

# SWAT phosphorus pools and cycling



# Taking a closer look at phosphorus pool ***initialization***




*Specified in model input file*

*Specified in model input file*

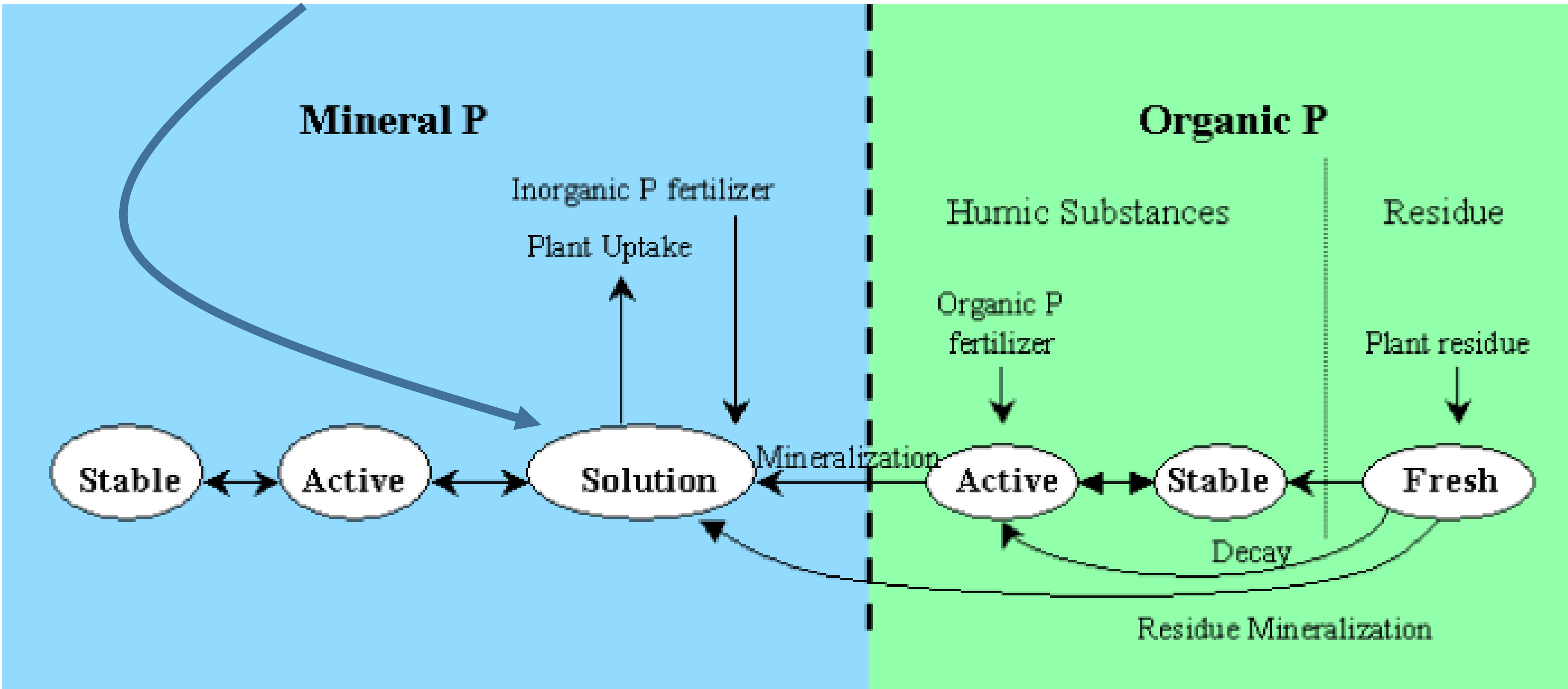
Initialized as function of solution P and a phosphorus availability index (PSP)

Initialized as function of organic N (which is initialized as function of soil organic C)

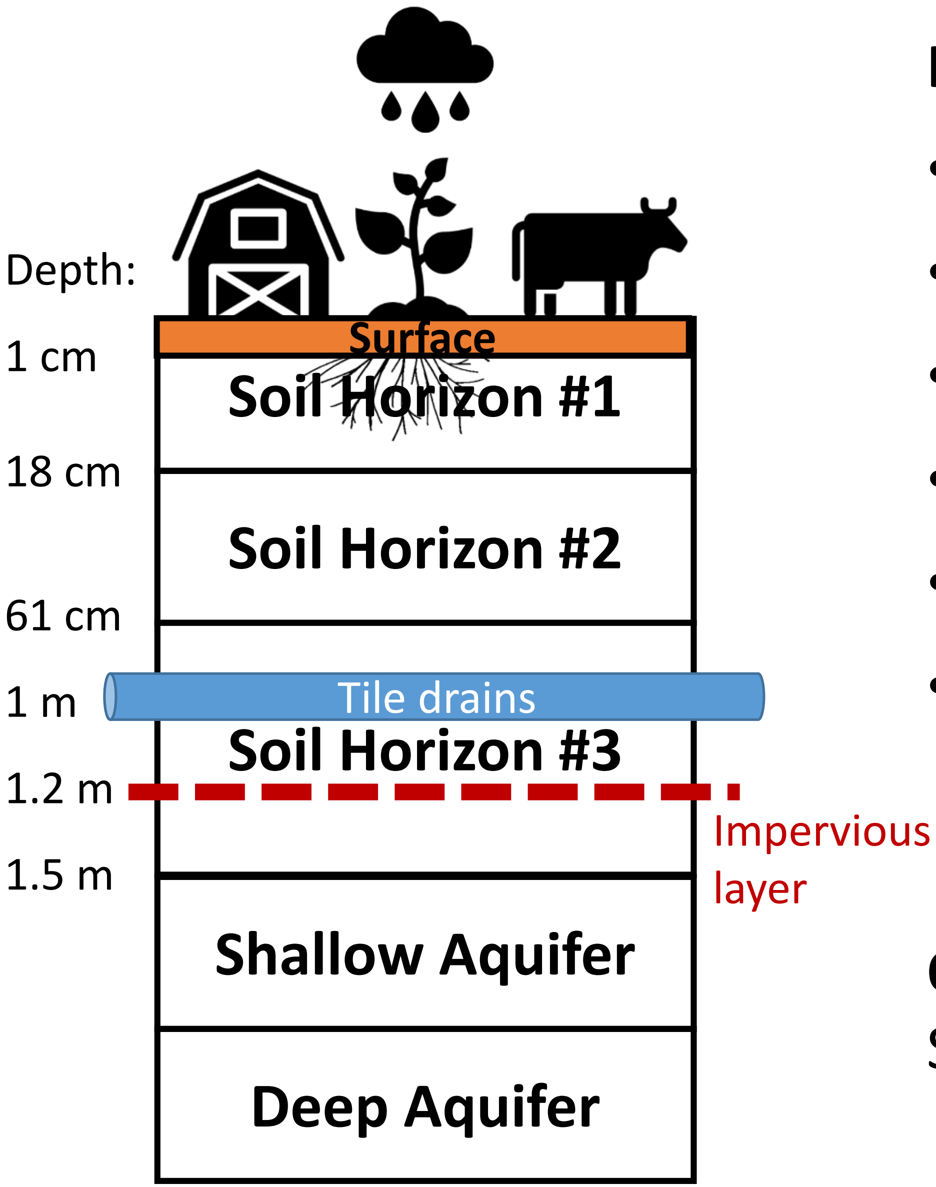
## *Can soil test phosphorus be input in SWAT?*

Perhaps? Rule of thumb:

Solution P = soil test phosphorus (Bray-1 P) * 0.5



# Example: one HRU (field)



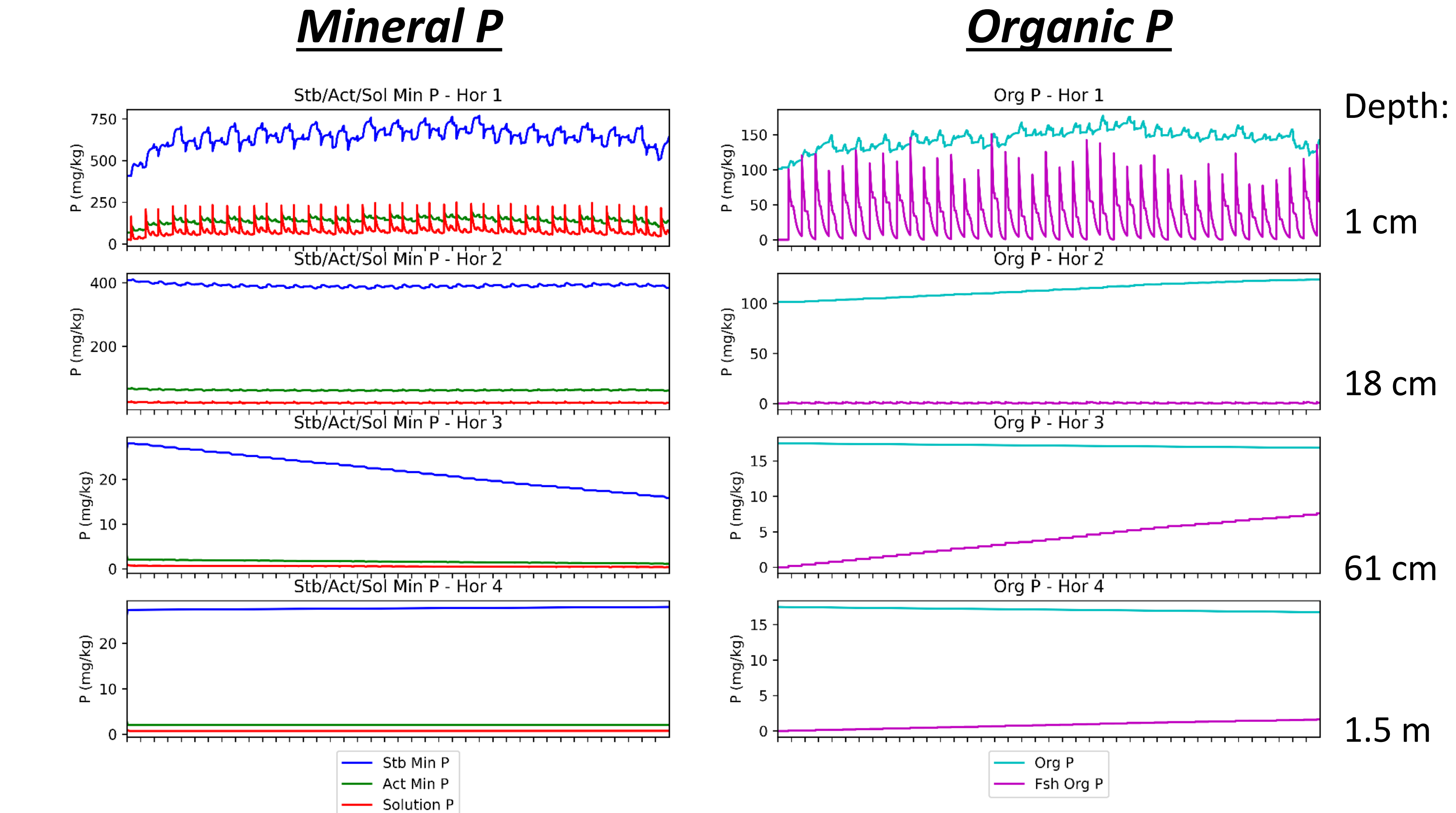

**HRU characteristics:**

- Corn-soybean rotation
- Tile drainage
- Hydrologic soil group C
- ~1% organic carbon
- ~25-40% clay
- P fertilizer applications of ~26 kg/ha/y

**Other:** CSWAT = 0 (old but reliable?), SOL_P_MODEL = 0 (new)

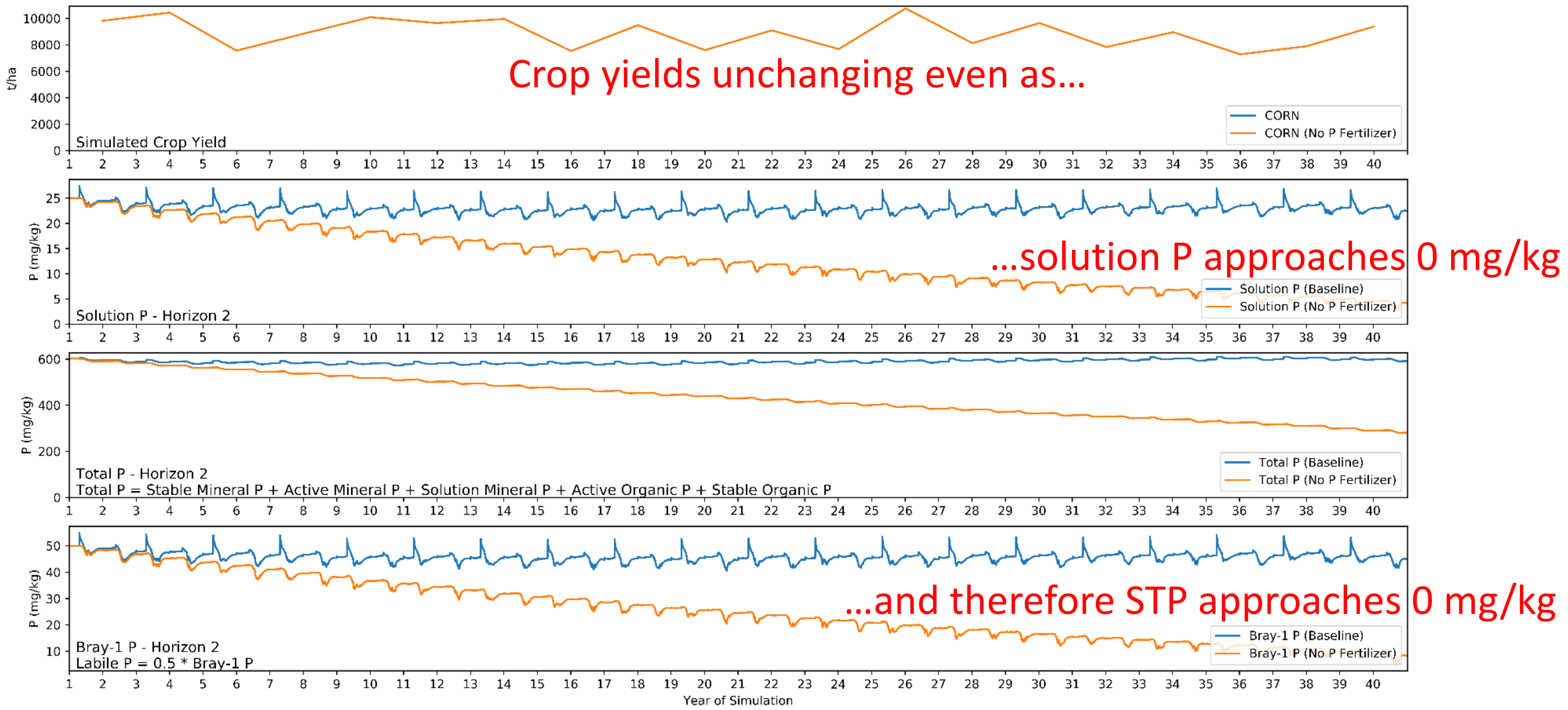
# P cycle simulation results by horizon at ~STP 50

***Promising:*** when using Rule of Thumb (Solution P = (Bray-1 P) * 0.5), P pools fairly steady under P fertilization ~ 26 kg/ha



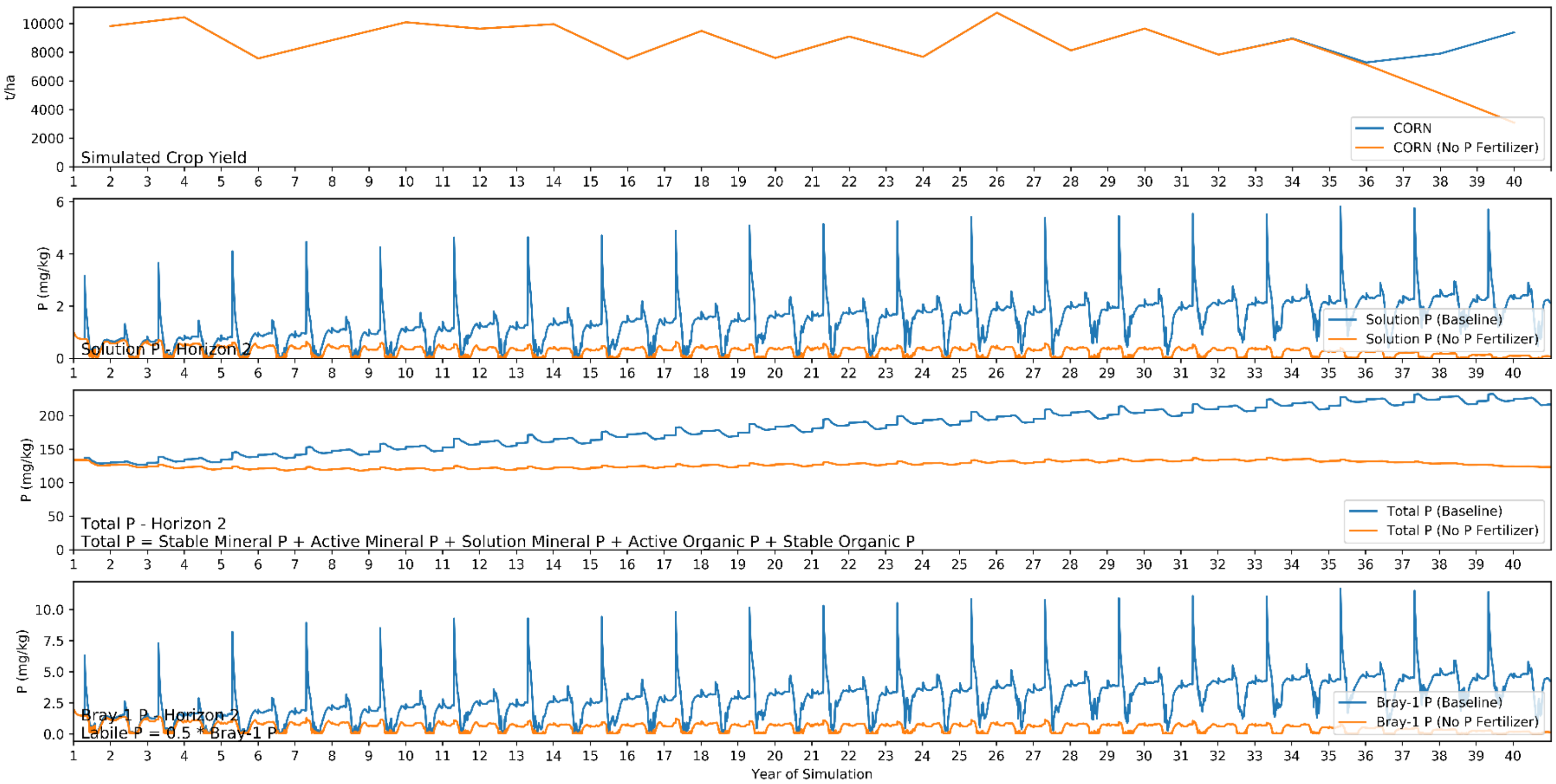
# P cycle simulation results in horizon #2 at ~STP 50

***Troubling:*** Simulated crop yield does not change over 40 years if P fertilizer application stops!



# P cycle simulation results in horizon #2 at ~STP 2

***Troubling:*** Initial solution P decreased to 1 mg/kg – crop yields decline after ~32 years



# P cycle simulation results by horizon at ~STP 50

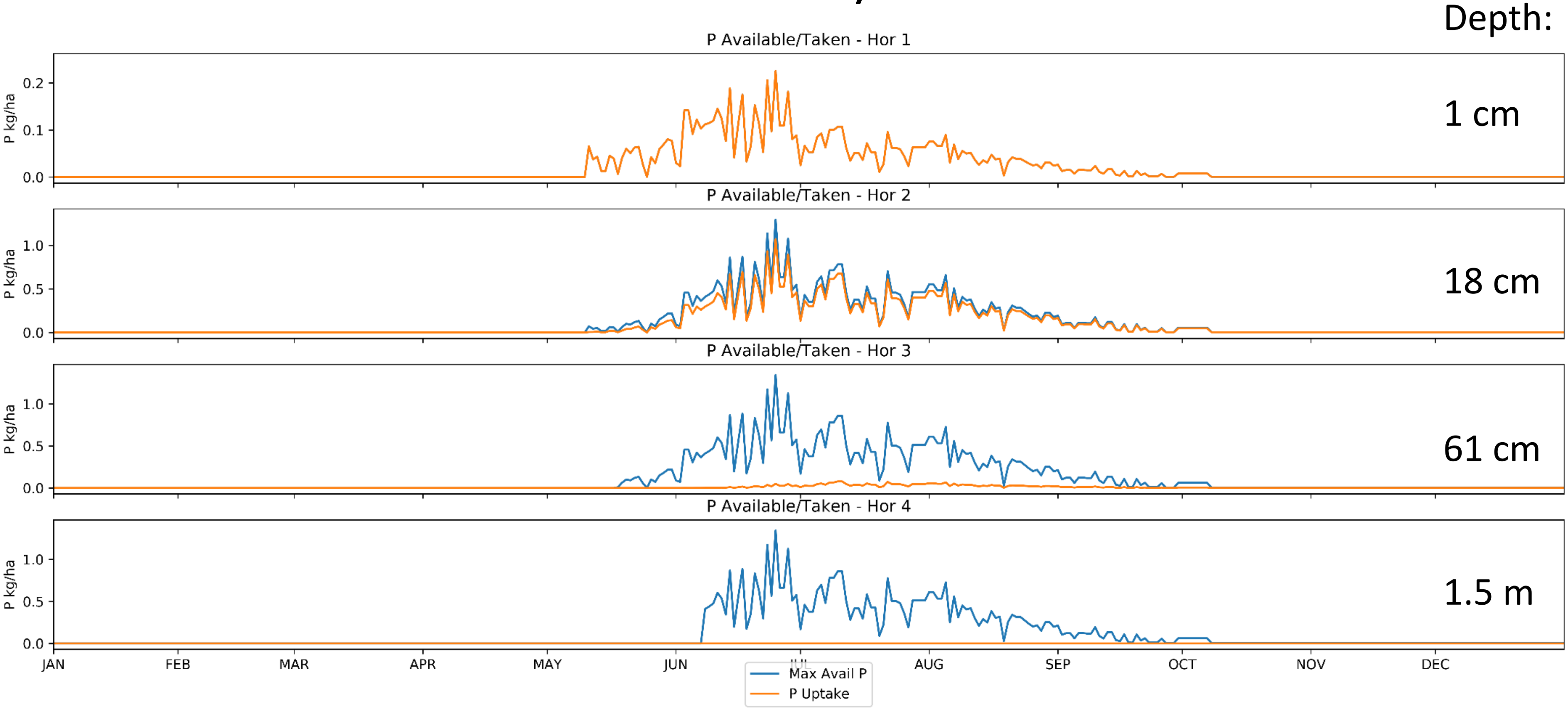
Over one year of simulation.

Why is crop growth not limited by low solution P?

P available (maximum P uptake from soil layer) ~= P uptake

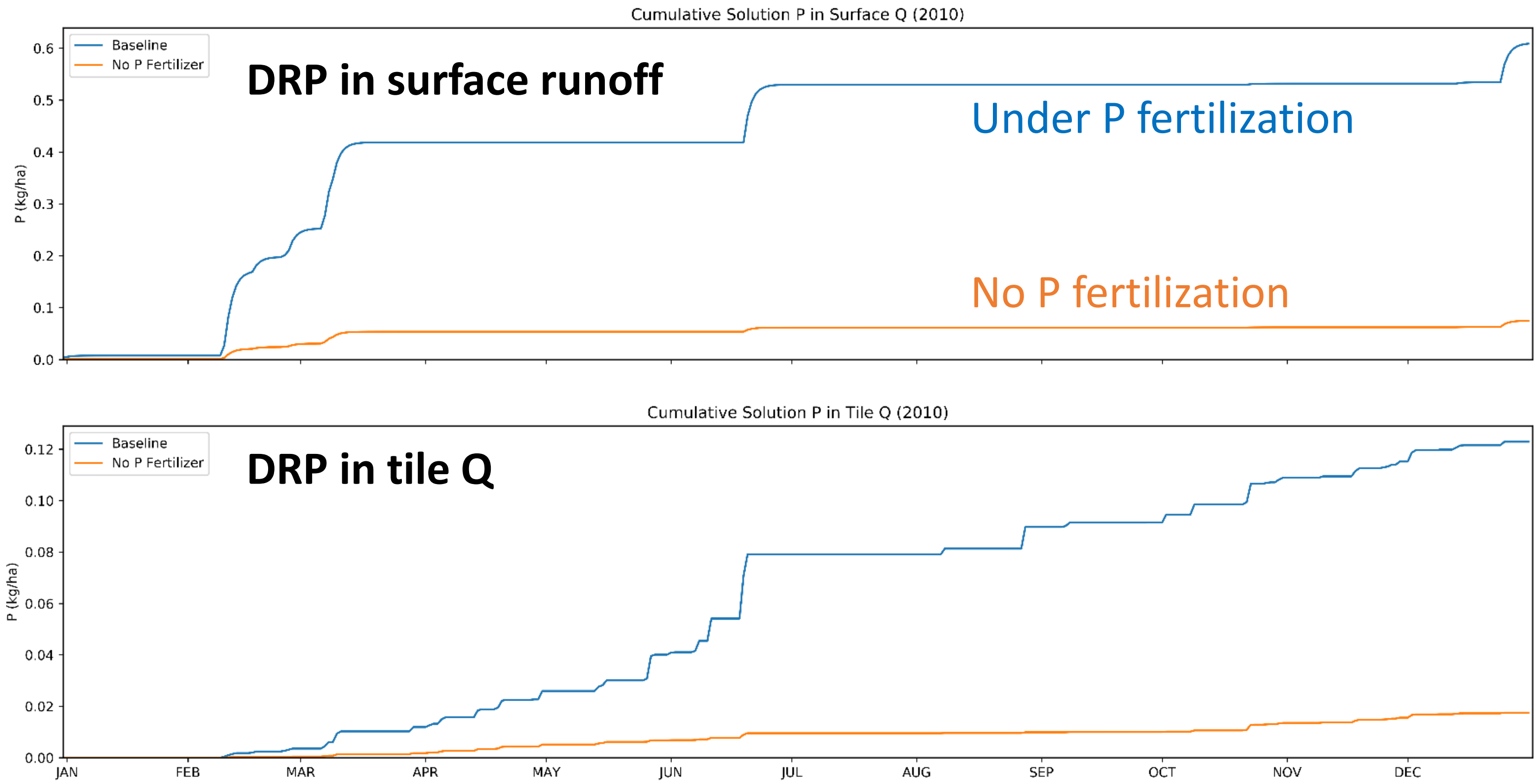
Plant uptake is not limited? No plant P stress simulated.

How does luxury P fit in?



# DRP export to the reach at ~STP 50

Over one year of simulation.
Solution P exported from one HRU (field):
In surface runoff: 0.6 kg/ha/y
Through subsurface drains: 0.12 kg/ha
Is this reasonable? Recall calibration issues.



# ***What other challenges (and opportunities) are we thinking about?***

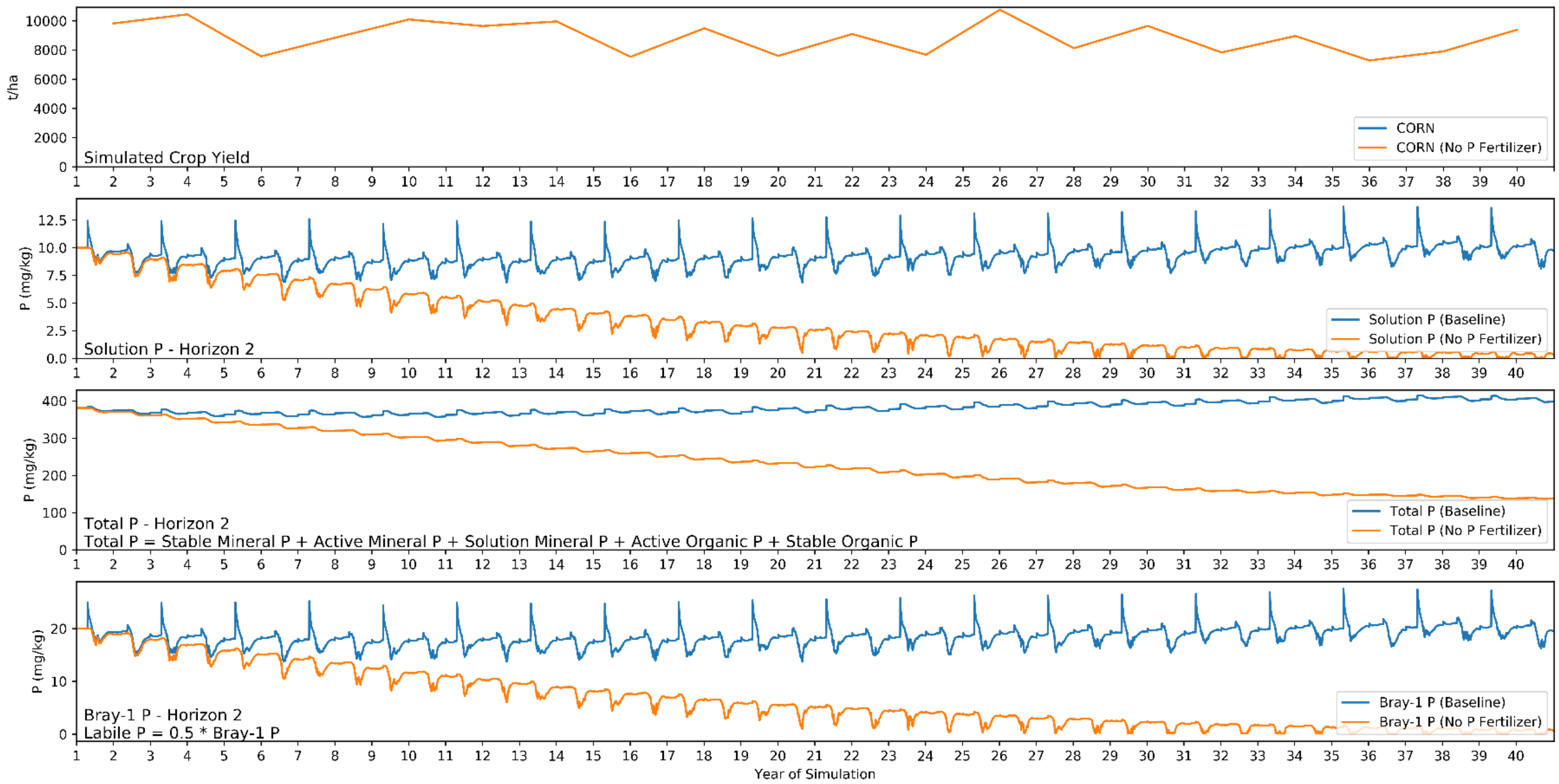
- Stratification of P in no-till system
- Relation of soil P to soil carbon
- Confusing nomenclature around P in SWAT
- pH can control P availability – but not in SWAT
- Streambed simulation of P limited in SWAT
- Better simulating manure and inorganic slow release fertilizers
- Capturing within-field variability of P

## **Conclusions:**

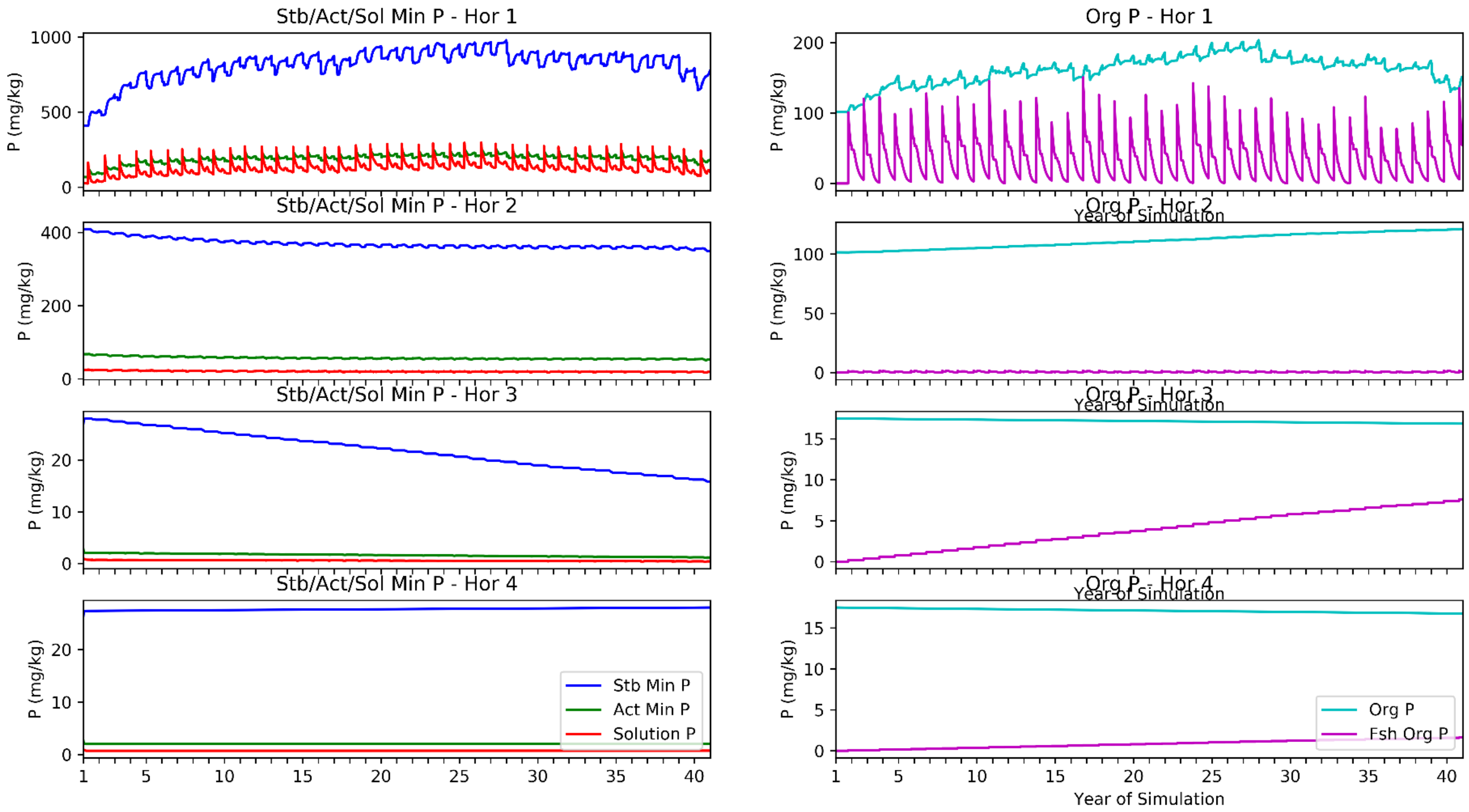
- Something is wrong with SWAT’s simulation of crop P stress under low soil P conditions. What do we fix? Additional pools? Difference relationship between STP and solution P?
- There are a lot of ways we can improve SWAT’s simulation of soil!

# P cycle simulation results in horizon #2 at ~STP 20

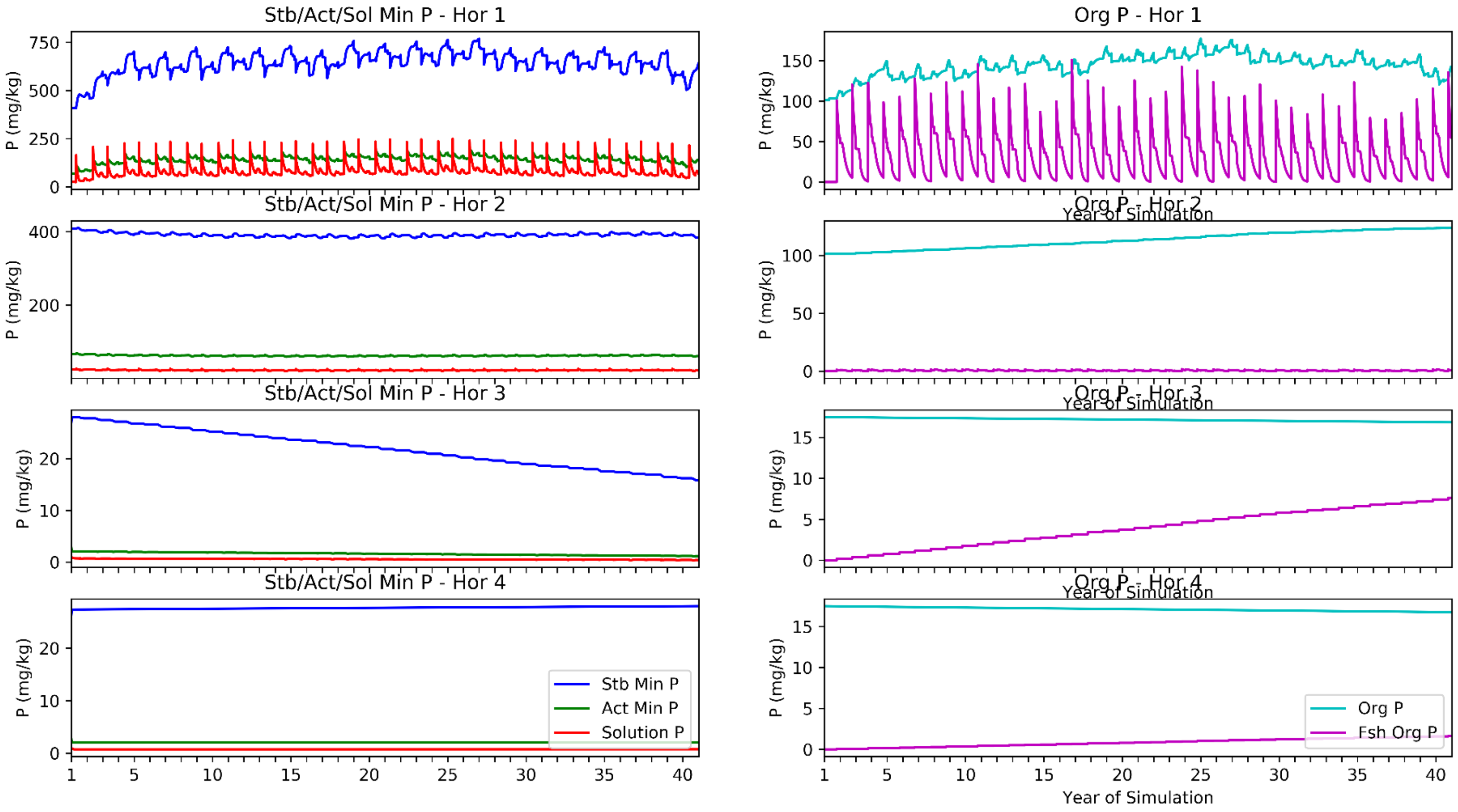
***Troubling:*** Initial solution P decreased to 10 mg/kg – still no change in crop yield!



# Stratification with no-till? No-till:



# Stratification with no-till? Till:



# Soil chemistry inputs (.chm file)

000010010 - Notepad

File Edit Format View Help

```
 .chm file Watershed HRU:10 Subbasin:1 HRU:10 Luse:SOYB Soil: 5829 Slope: 0-9999 12/1/2016 12:00:00 AM ArcSWAT 2012.10_0.14
Soil Nutrient Data
 Soil Layer             :          1           2           3           4           5           6           7           8           9          10
 Soil NO3 [mg/kg]       :       0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
 Soil organic N [mg/kg] :       0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
 Soil labile P [mg/kg]  :       1.00        1.00        1.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
 Soil organic P [mg/kg] :       0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
 Phosphorus perc coef   :      10.00       10.00       10.00       10.00       10.00       10.00       10.00       10.00       10.00       10.00
Soil Pesticide Data
 Pesticide  Pst on plant    Pst in 1st soil layer Pst enrichment
   #           [kg/ha]            [kg/ha]            [kg/ha]
                  0.00               0.00               0.00
                  0.00               0.00               0.00
                  0.00               0.00               0.00
                  0.00               0.00               0.00
                  0.00               0.00               0.00
                  0.00               0.00               0.00
                  0.00               0.00               0.00
                  0.00               0.00               0.00
                  0.00               0.00               0.00
                  0.00               0.00               0.00
```

# Soil properties inputs (.sol file)

000010010 - Notepad

File Edit Format View Help

```
.Sol file Watershed HRU:10 Subbasin:1 HRU:10 Luse:SOYB Soil: 5829 Slope: 0-9999 12/1/2016 12:00:00 AM ArcSWAT 2012.10_0.14
Soil Name: Morley
Soil Hydrologic Group: C
Maximum rooting depth(mm) : 1520.00
Porosity fraction from which anions are excluded: 0.050
Crack volume potential of soil: 0.100
Texture 1                 : L-SICL-CL
Depth                [mm]:      180.00      610.00      1520.00
Bulk Density Moist [g/cc]:        1.45        1.63         1.70
Ave. AW Incl. Rock Frag  :        0.22        0.13         0.10
Ksat. (est.)      [mm/hr]:       32.40        7.96         7.96
Organic Carbon [weight %]:        1.16        0.20         0.20
Clay           [weight %]:       24.50       38.50        33.50
Silt           [weight %]:       36.70       54.70        32.30
Sand           [weight %]:       38.80        6.80        34.20
Rock Fragments   [vol. %]:        6.00        9.00         9.00
Soil Albedo (Moist)      :        0.30        0.30         0.30
Erosion K                :        0.37        0.43         0.43
Salinity (EC, Form 5)    :        0.00        0.00         0.00
Soil pH                  :        6.10        6.50         7.30
Soil CACO3               :        0.00        0.00         0.00
```

# Management inputs (.mgt file)

000010010Fert - Notepad

Hourly Weather Forecast for Columbus, OH - The Weather Channe

File Edit Format View Help

```
 .mgt file Watershed HRU:1 Subbasin:1 HRU:1 Luse:CORN Soil: 5779 Slope: 0-9999 12/1/2016 12:00:00 AM ArcSWAT 2012.10_0.14
              0    | NMGT:Management code
Initial Plant Growth Parameters
              0    | IGRO: Land cover status: 0-none growing; 1-growing
              0    | PLANT_ID: Land cover ID number (IGRO = 1)
           0.00    | LAI_INIT: Initial leaf are index (IGRO = 1)
           0.00    | BIO_INIT: Initial biomass (kg/ha) (IGRO = 1)
           0.00    | PHU_PLT: Number of heat units to bring plant to maturity (IGRO = 1)
General Management Parameters
           0.15    | BIOMIX: Biological mixing efficiency
          70.00    | CN2: Initial SCS CN II value
           0.60    | USLE_P: USLE support practice factor
           0.00    | BIO_MIN: Minimum biomass for grazing (kg/ha)
          0.000    | FILTERW: width of edge of field filter strip (m)
Urban Management Parameters
              0    | IURBAN: urban simulation code, 0-none, 1-USGS, 2-buildup/washoff
              0    | URBLU: urban land type
Irrigation Management Parameters
              0    | IRRSC: irrigation code
              0    | IRRNO: irrigation source location
          0.000    | FLOWMIN: min in-stream flow for irr diversions (m^3/s)
          0.000    | DIVMAX: max irrigation diversion from reach (+mm/-10^4m^3)
          0.000    | FLOWFR: : fraction of flow allowed to be pulled for irr
Tile Drain Management Parameters
       1000.000    | DDRAIN: depth to subsurface tile drain (mm)
         24.000    | TDRAIN: time to drain soil to field capacity (hr)
         24.000    | GDRAIN: drain tile lag time (hr)
Management Operations:
              6    | NROT: number of years of rotation
Operation Schedule:
  4 21          3    1          141.64272   0.01
  4 21          3    2           26.18984   0.95
  4 22          6    6
  5  6          1   19         1762.00000
 10 14          5
                0
  5 20          3    2           26.18984   0.95
  5 24          1   56         1604.00000
 10  7          5
                0
  4 21          3    1          141.60897   0.01
  4 21          3    2           26.13827   0.95
  4 22          6    6
  5  6          1   19         1762.00000
 10 14          5
                0
```