APLE Phosphorus Model

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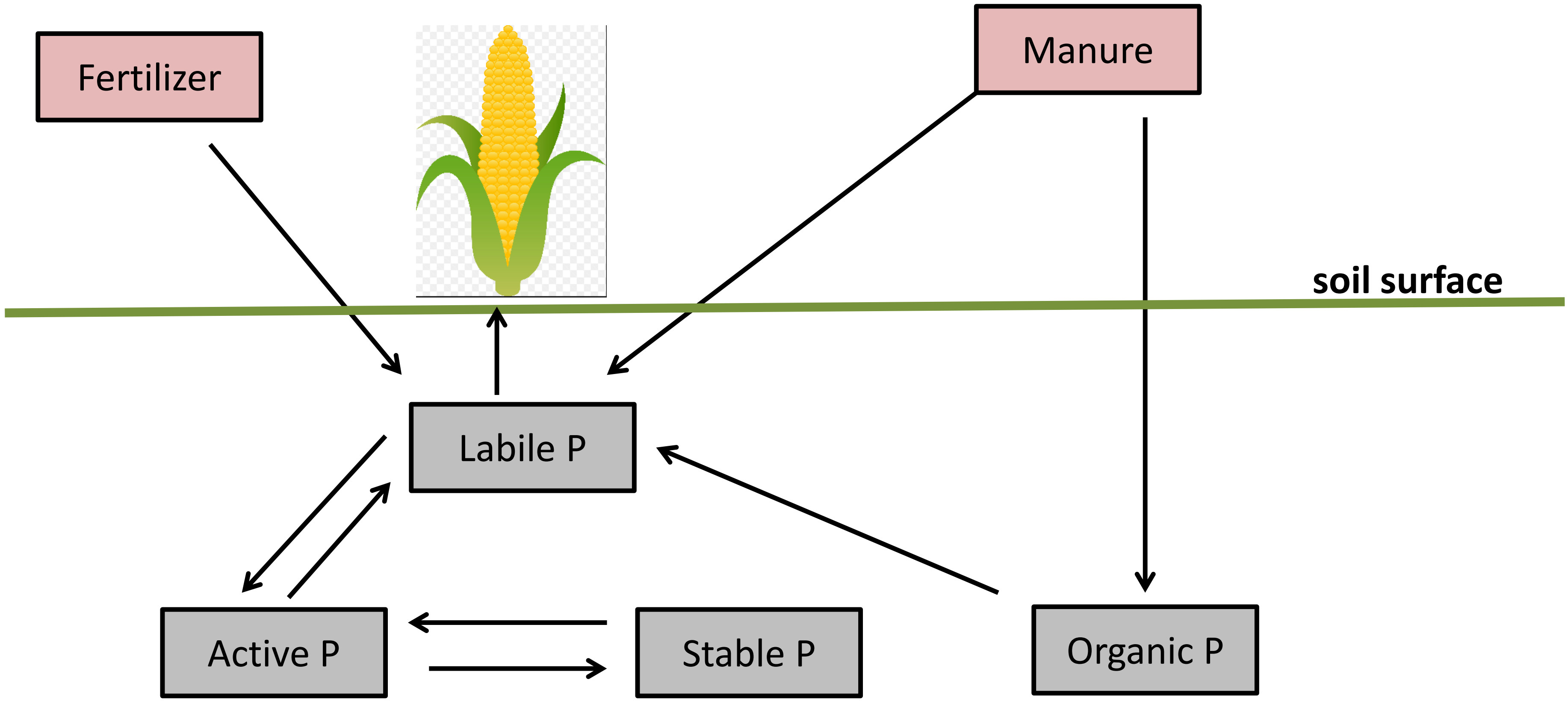
Annual P Loss Estimator (APLE) tool

- Developed by Vadas, et al. (USDA-ARS)
- Annual time step
- Edge-of-field estimation
- Simulates sediment and dissolved P surface losses from soil, manure, and fertilizer sources
- Minimal subsurface loss or leaching to groundwater simulated

Diagram of APLE Nutrient Sources and Soil Pools



Equations to estimate Manure runoff P, Fertilizer runoff P, Sediment P loss, and Dissolved Soil P runoff

(Adapted from Vadas, et al. 2007)

Nutrient Application Assumptions

- Application rates are user-defined by season
- Fertilizer
- Manure
  - solid or liquid forms (user-defined)
  - Direct excretion of manure (i.e. pasture) is considered a separate manure source
  - Proportioned as water-extractable P (WEP) and non-WEP

Nutrient Application Assumptions

- For manure <15% solid, an assumed 60% of application infiltrates into the soil profile and is unavailable for surface loss
- Nutrient incorporation (user-defined) also removes P available for surface loss
- Dissolved manure P loss is estimated from the manure WEP on the soil surface

Manure and Fertilizer Surface Runoff

P applied − P incorporation and infiltration

↓

P on surface X Availability factor

> Fertilizer: 100%
> Manure: % WEP + % Non-WEP mineralized

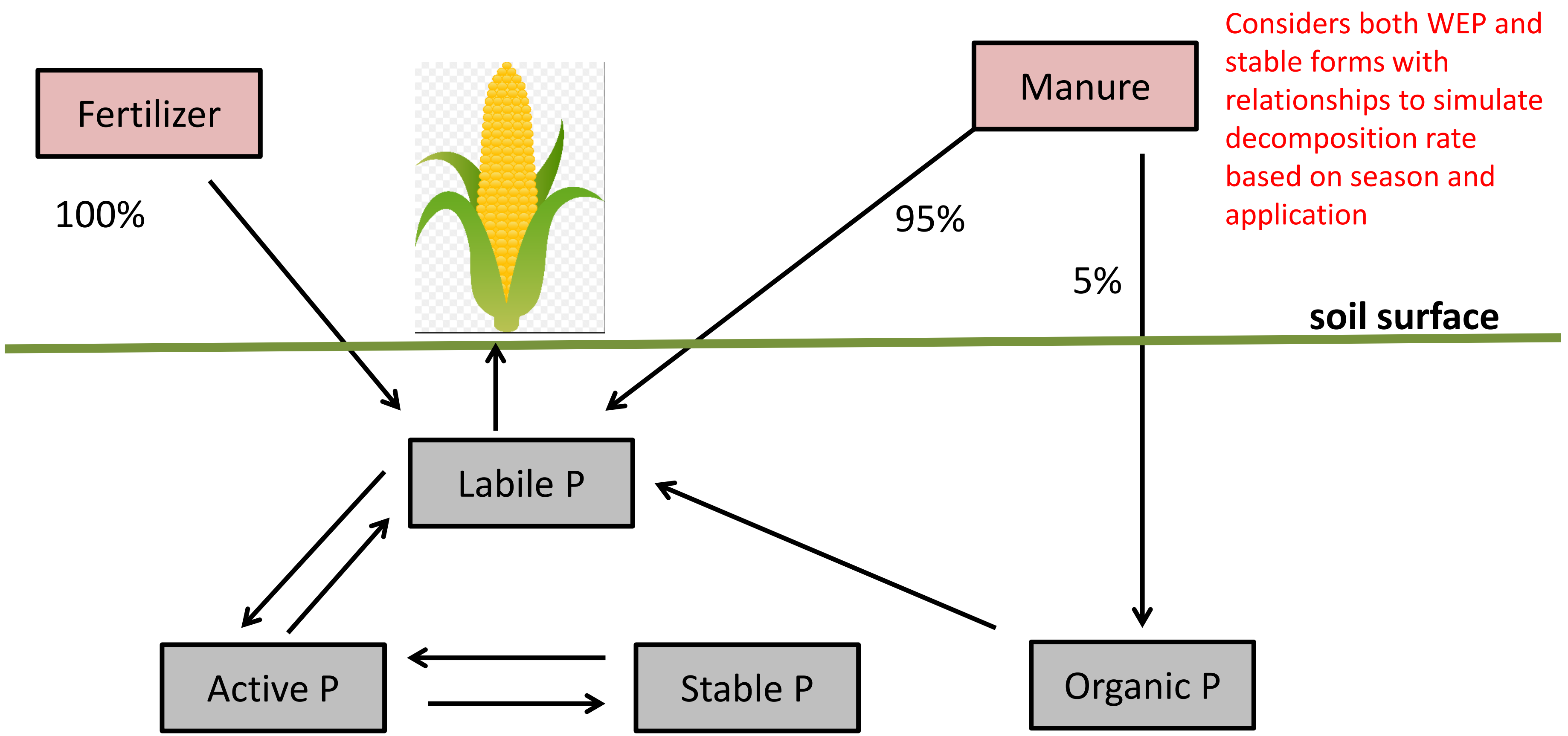
↓

Available WEP on Surface X $\frac{\text{Runoff}}{\text{Precipitation}}$ X Distribution Factor

↓

Dissolved P in Surface Runoff

Diagram of APLE Nutrient Sources and Soil Pools



Equations to estimate Manure runoff P, Fertilizer runoff P, Sediment P loss, and Dissolved Soil P runoff

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APLE Soil Pools

- Soil pool simulation is largely an evolution of the EPIC/SWAT soil routines
- Pools are initialized from soil test P, % clay, and % OM
- Soil pools can simulate two soil depths, especially a stratified top layer due to pasture or no-till
- Labile P is easily exchangeable P available for plant uptake or runoff
- Active P is more stable and less easily desorbed, but in equilibrium with Labile pool

Sediment P Loss

Sediment P Loss (kg/ha) = Eroded sediment * Soil Total P * P Enrichment Ratio

- Eroded sediment = soil loss due to erosion
- Soil Total P = total P content of all soil pools
- P Enrichment Ratio = ratio of total P in eroded soil versus surface soil

Dissolved Soil P Loss

Dissolved Soil Runoff P (kg/ha) = Soil Labile P * 0.005 * Annual Runoff * 10^{-6}

Data Input Needs

- Soil properties:
  - Soil depth (2 layers)
  - Soil Test P
  - Clay and OM percentage (per soil layer)

- Transport factors:
  - Annual precipitation
  - Annual runoff and sediment loss

- Field properties:
  - Field size
  - Grazing animals (count and # days)
  - Crop uptake
  - Nutrient application and depth of incorporation

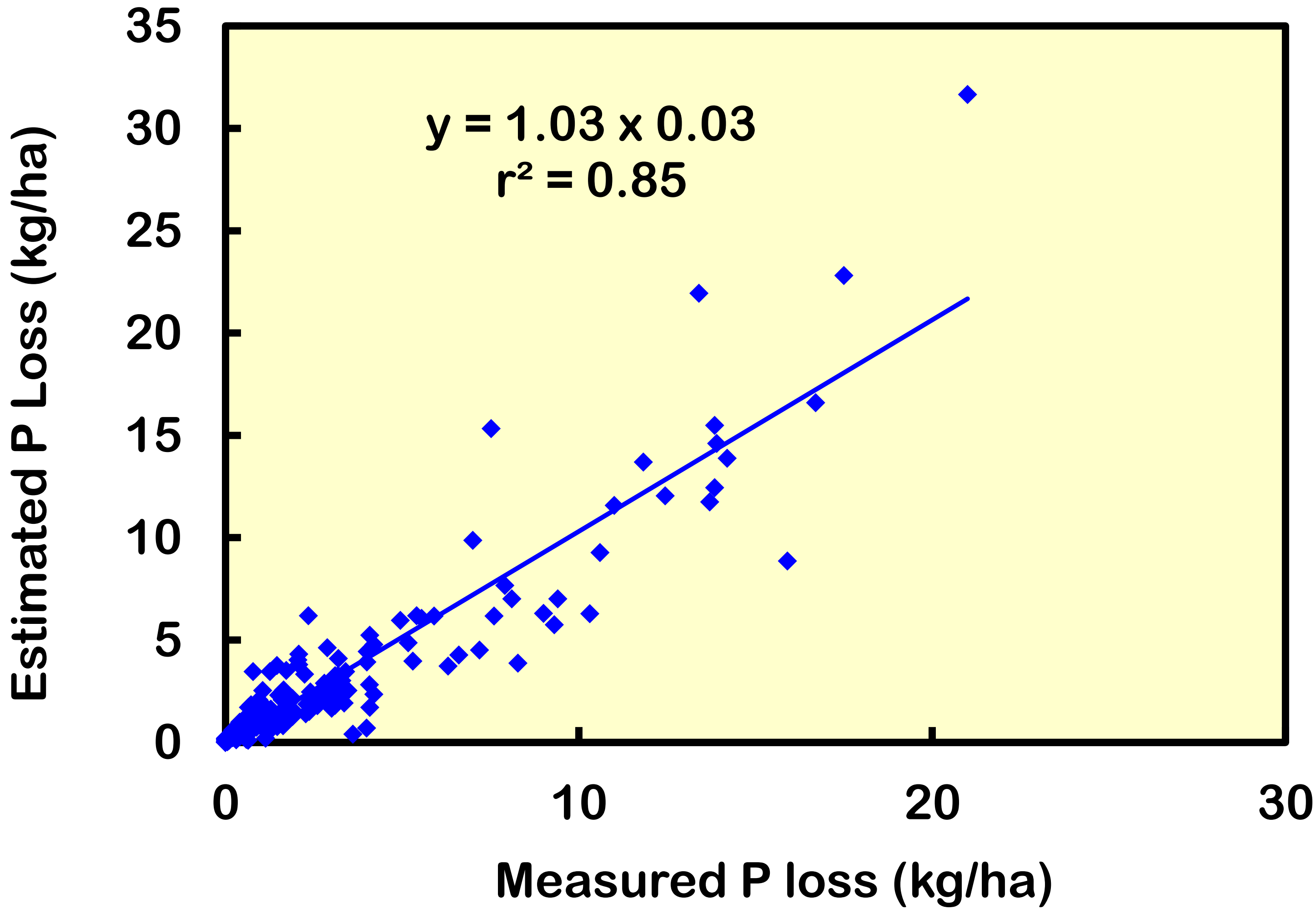
APLE Output

		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Sediment P Loss	lb/ac	2.75	2.77	2.76	2.75	2.74	2.72	2.71	2.69	2.68	2.66
Soil Dissolved P Loss	lb/ac	0.14	0.16	0.17	0.18	0.19	0.20	0.20	0.21	0.21	0.22
Manure Dissolved P Loss	lb/ac	0.09	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Fertilizer Dissolved P Loss	lb/ac	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Dissolved P Loss	lb/ac	0.23	0.27	0.28	0.29	0.30	0.31	0.31	0.32	0.32	0.33
Total P loss	lb/ac	2.98	3.03	3.05	3.05	3.04	3.03	3.02	3.01	3.00	2.99
Final Mehlich 3 Soil P 1st Layer	ppm	79	87	93	97	100	103	105	107	109	110
Final Mehlich 3 Soil P 2nd Layer	ppm	39	39	39	39	39	39	39	40	40	40
Final Mehlich 3 Soil P Entire Soil	ppm	44	45	45	46	46	47	47	48	48	49

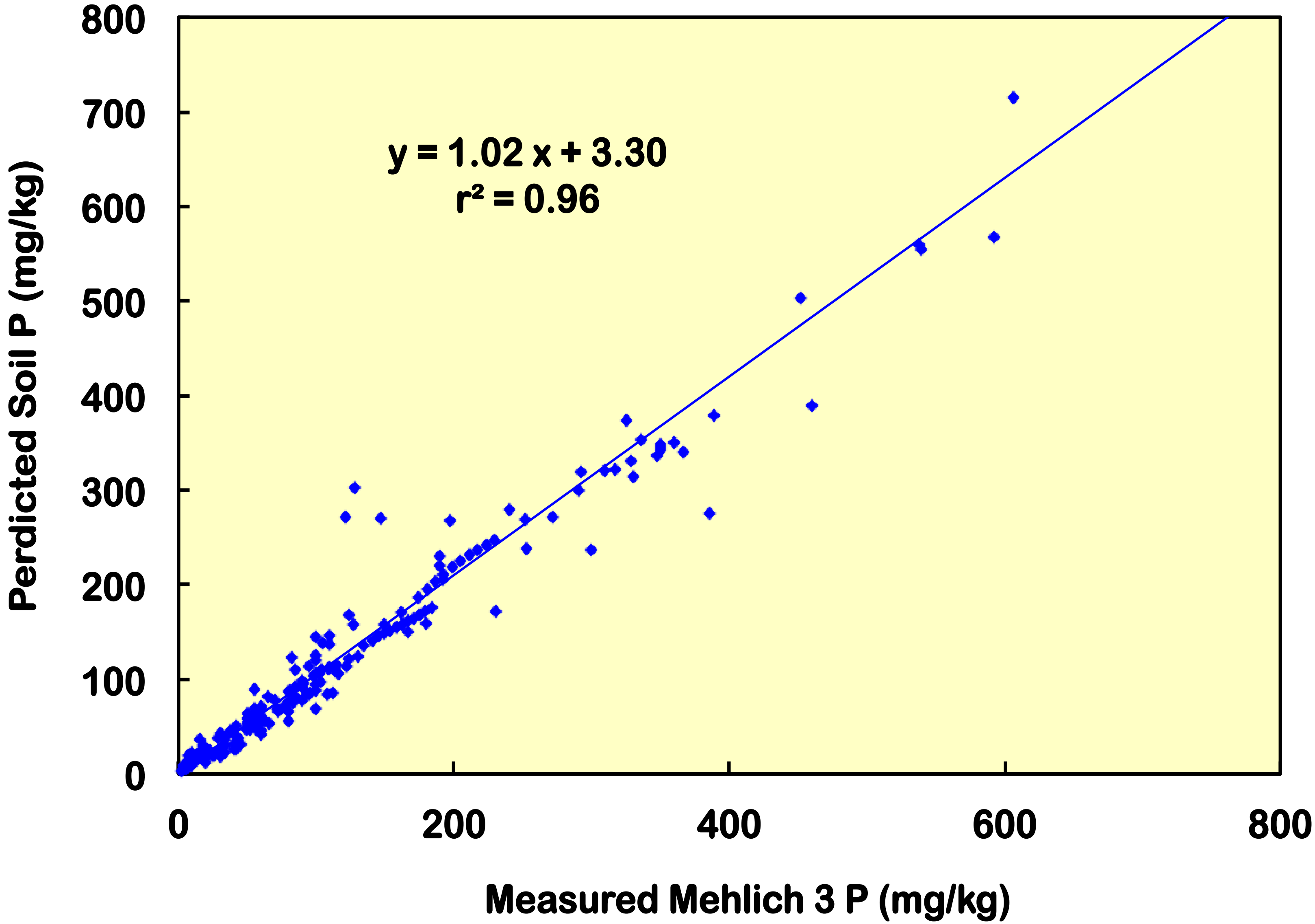
Model Validation

- P loss in runoff
  - Measured data from 28 crop studies from 13 states, Australia, and Ireland; 14 pasture studies from 5 states, Australia, and New Zealand
- Soil P dynamics
  - Measured data from 19 studies monitoring changes in soil P from 1 to 25 years
- Under all scenarios, the model was <u>not</u> calibrated differently

APLE P Loss Validation: Surface Runoff



APLE Soil P Validation



Current Research Objectives

- The objective of my research is to evaluate, identify, and improve the mechanics and representation of soil P as simulated in the Chesapeake Bay Watershed Model

- Primary areas of consideration:
  - Nutrient cycling within soil pools
  - Fate and transport mechanisms
  - Edge-of-field (EOF) base targets for cropland and pasture

Status

- Using data from HSPF and Scenario Builder to estimate average EOF targets for three landuses (*hwm, lwm, pas*) at the county scale
- Estimations are model calibration period of 1992-2005
- Currently running initial scenarios for *hwm* 1992 to confirm model codes
- Gathering and organizing data for other years

References

<u>Model Development and Validation:</u>

Vadas, P.A., P.J.A. Kleinman, and A.N. Sharpley. 2004. A simple method to predict dissolved phosphorus in runoff from surface-applied manures. J. Environ. Qual. 33:749-756.

Vadas, P.A., B.E. Haggard, and W.J. Gburek. 2005a. Predicting dissolved phosphorus in runoff from manured field plots. J. Environ. Qual. 34:1347-1353.

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Vadas, P.A. 2006. Distribution of phosphorus in manure slurry and its infiltration after application to soils. J. Environ. Qual. 35:542-547.

Vadas, P.A., W.J. Gburek, A.N. Sharpley, P.J.A. Kleinman, P.A. Moore, 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.

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

Vadas, P.A., and M.J. White. 2010. Validating Soil Phosphorus Routines in the Swat Model. Trans. ASABE 53:1469-1476.

<u>Soil Pools (Epic/SWAT):</u>

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.

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

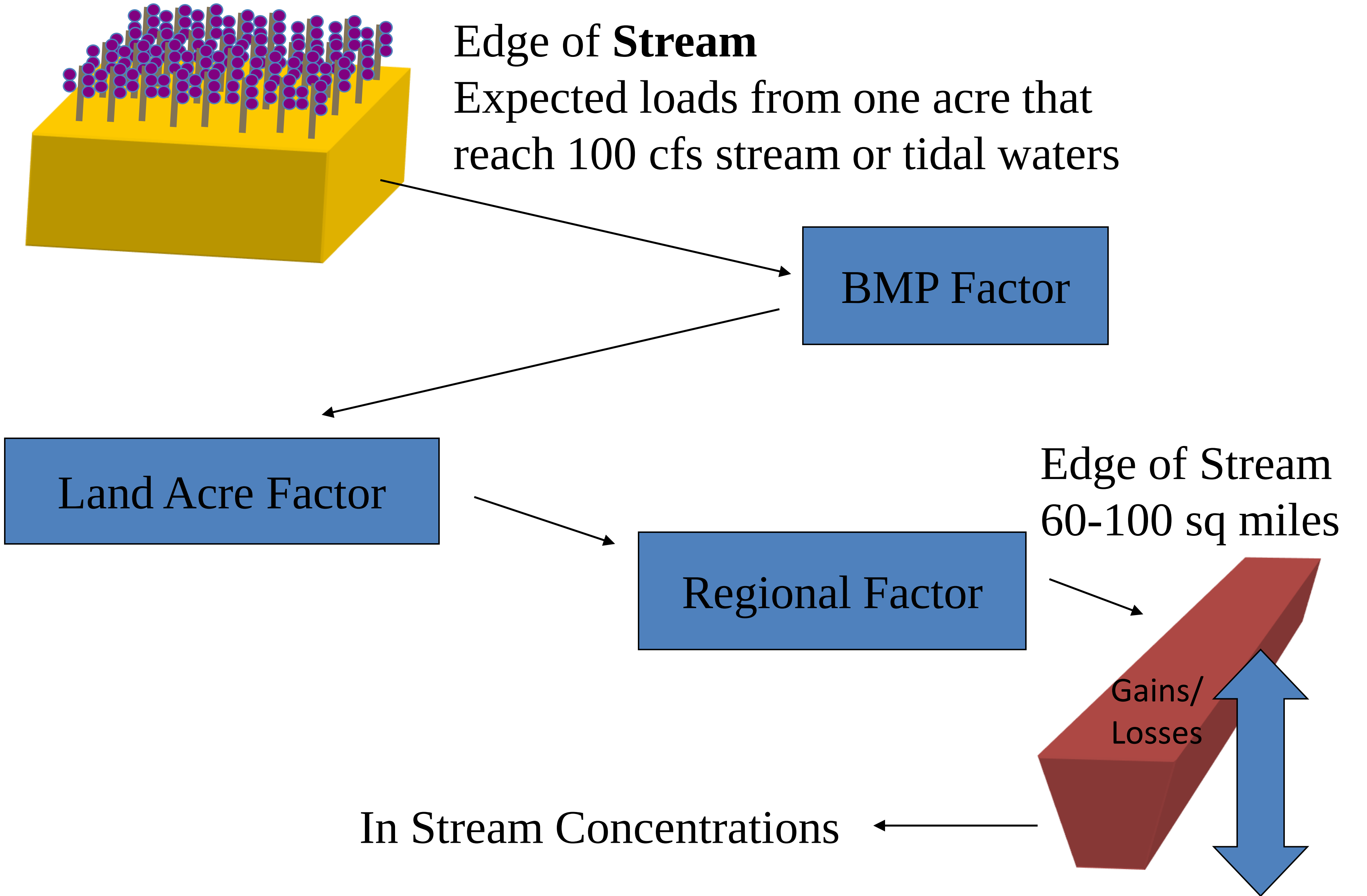
<u>Leaching Studies:</u>

Nelson, N.O., and J.E. Parsons. 2006. Modification and validation of GLEAMS for prediction of phosphorus leaching in waste-amended soils. Trans. ASABE 49:1395-1407.

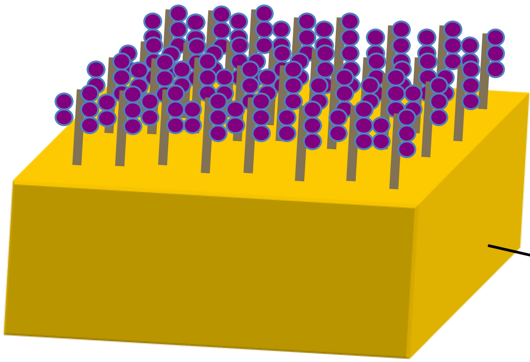
Nelson, N.O., J.E. Parsons, and R.L. Mikkelsen. 2005. Field-scale evaluation of phosphorus leaching in acid sandy soils receiving swine waste. J. Environ. Qual. 34:2024-2035.

EXTRAS

Scale in Phase 5 - Nutrients



Scale in Phase 5 - Sediment



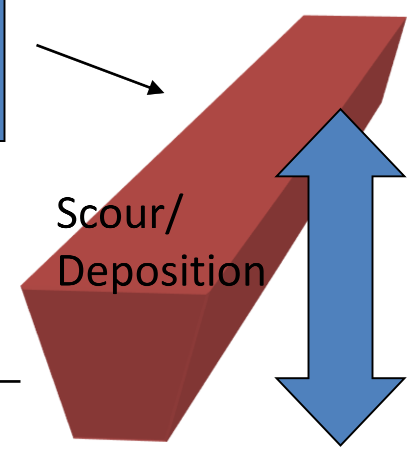
Edge of Field
Expected loads from one acre

BMP Factor

Land Acre Factor

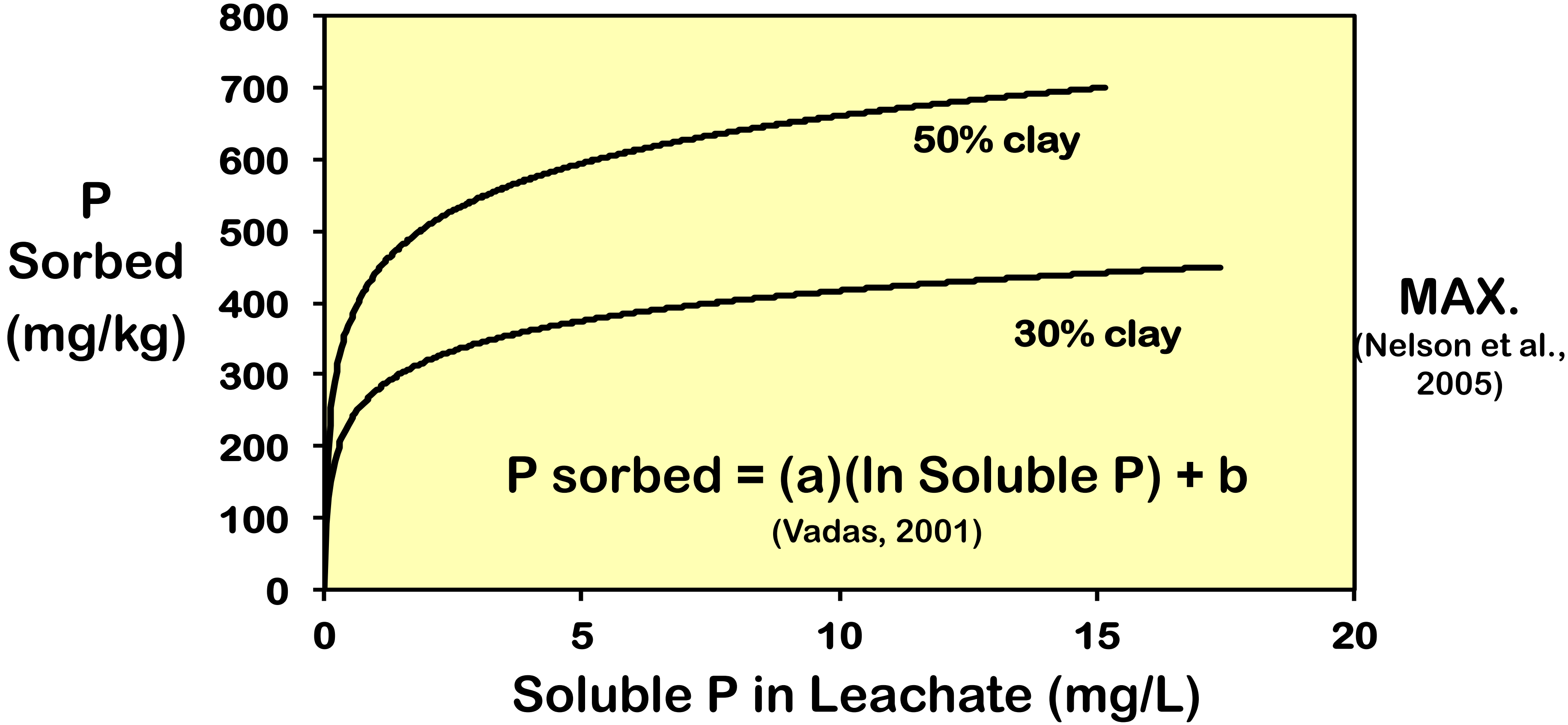
Delivery Factor

Edge of Stream
60-100 sq miles



In Stream Concentrations

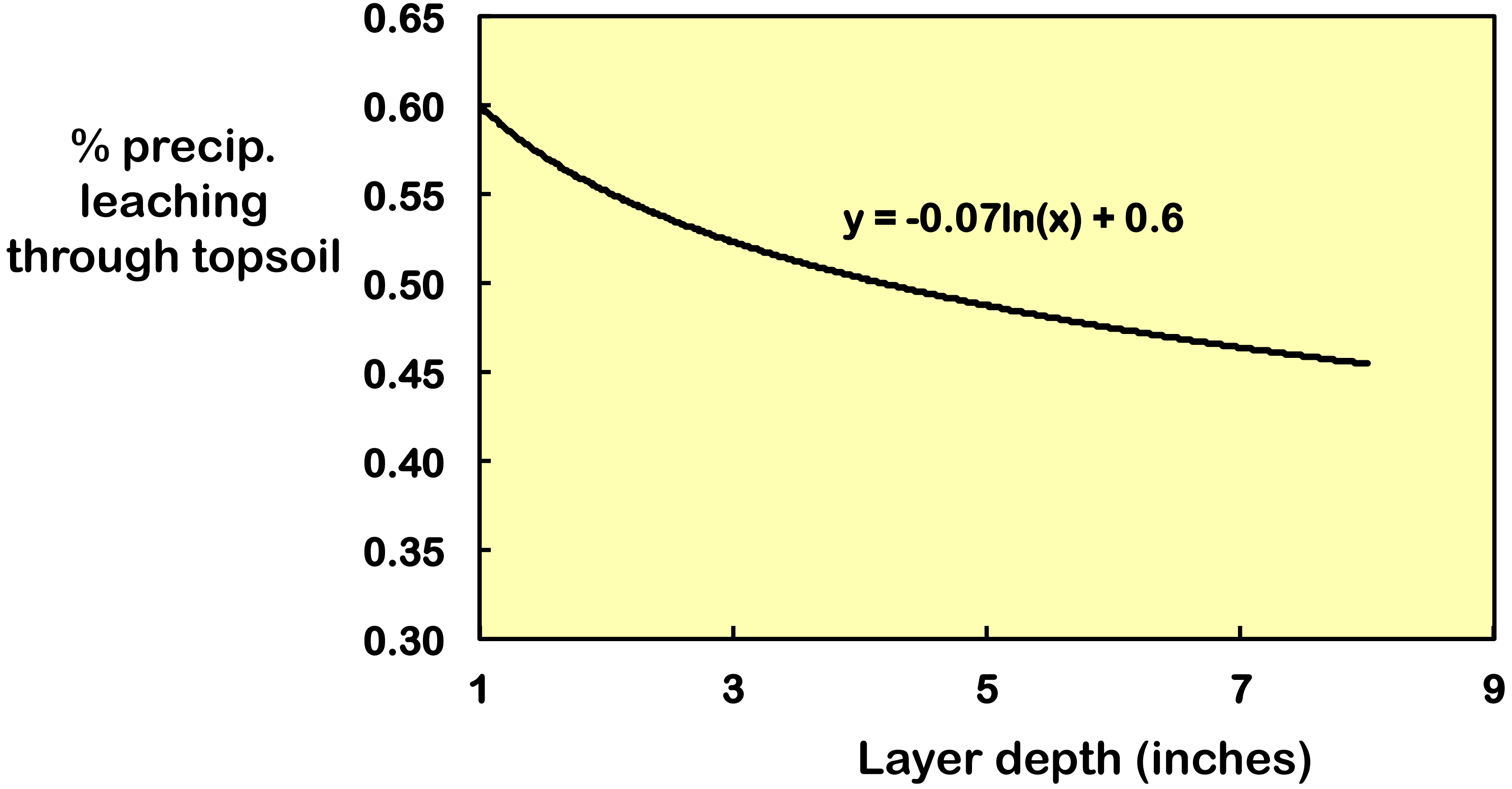
P Leaching within Topsoil



a and b from soil clay

P sorbed = Labile P + 1/2 added P that remains Labile

P Leaching within Topsoil



Nelson et al. (2005)

Grazing Animals Manure Generation: APLE vs. Scenario Builder

Animal Type	Daily Fecal Production (kg)	Fecal Total P content (kg/kg)
Lactating Dairy Cow	8.9	0.0088
Dairy Heifer	3.7	0.0054
Dairy Dry Cow	4.9	0.0061
Dairy Calf	1.4	0.0054
Beef Cow	6.6	0.0067
Beef Calf	2.7	0.0092

Animal Type and AU count	Daily Fecal Production (lbs) per AU	Daily Fecal Production (kg) per animal	Fecal TP content (kg/kg)
Beef (1.14)	58	23.10	0.000726
Dairy (0.74)	86	52.76	0.000499
other cattle (2.08)	64.39	14.05	0.000454

Other animals to consider?

- Horses
- Goats
- Sheeps and Lambs