Model Parameter Uncertainty Analysis for an Annual Field-Scale P Loss Model

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Sources of Model Uncertainty

- Model structure error
  - All models are approximations
  - “All models are wrong, some are useful”
- Model input error (variables such as rainfall, soil test P)
  - Measurement errors
  - Unrepresentative values
- Model parameter error (Generally obtained through calibration)
  - Incorrect optimization targets
  - Inaccurate, incomplete, or unrepresentative calibration data

APLE model equations

$$P_{tot} = P_{sed} + DP_{soil} + DP_{man} + DP_{fert}$$

P_{tot} is the total annual P loss from surface runoff (kg ha^{-1}),

P_{sed} is annual sediment P loss from eroded soil (kg ha^{-1}),

DP_{soil} is annual DRP loss in runoff from soil (kg ha^{-1}),

DP_{man} is annual DRP loss in runoff from applied manure (kg ha^{-1}),

DP_{fert} is annual DRP loss in runoff from applied fertilizer (kg ha^{-1}).

Objectives

1. Estimate the uncertainty associated with five regression equations used in APLE

2. Evaluate how the parameter uncertainties affect model prediction uncertainties

APLE model equations

$$P_{sed} = ER \cdot PER \cdot TP \cdot 10^{-6}$$

$$PER = C_1 \cdot ER^{C2}$$

$$TP = LP \cdot (1\text{-}PAI)/PAI \ + 4(LP \cdot (1\text{-}PAI)/PAI\ ) + OP$$

$$PAI = -C_3 \cdot \ln(\%Clay) + C_4 \cdot LP - C_5 \cdot SOC + C_6$$

ER is the annual erosion rate (kg ha^{-1}),
PER is the P enrichment ratio
TP is total soil P (mg kg^{-1}),

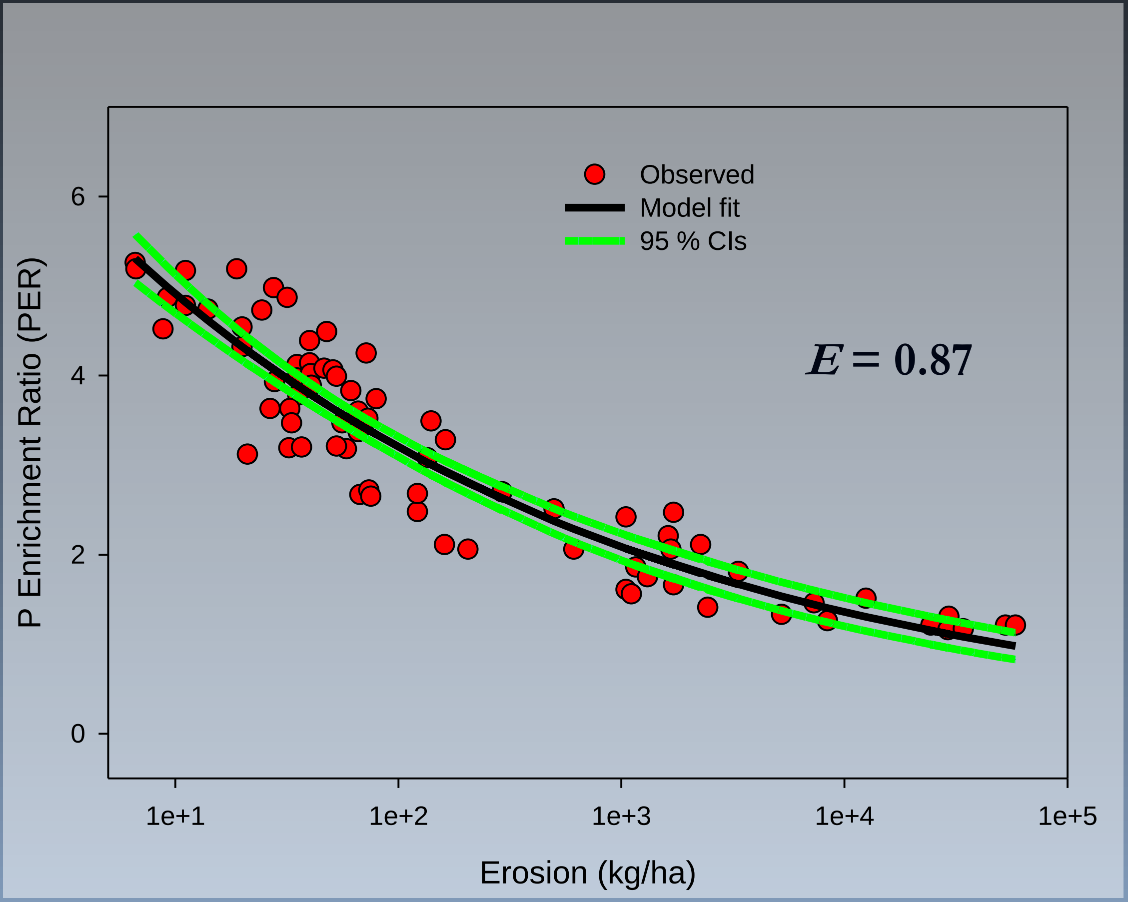
LP is labile P,
OP is organic P,
%Clay is clay content of soil,
SOC is soil organic carbon

Methods: Objective 1

- **Fit data using least squares regression**
- **Calculated 95 % confidence intervals (CIs) for the five equations**
  - **Represent uncertainty associated with <u>mean</u> response of the model**
- **Calculated 95 % prediction intervals**
  - **Accounts for parameter uncertainty AND unexplained variability**
  - **Used for making predictions for a single observation**

Results: Objective 1

P enrichment ratio (PER) fits and uncertainties

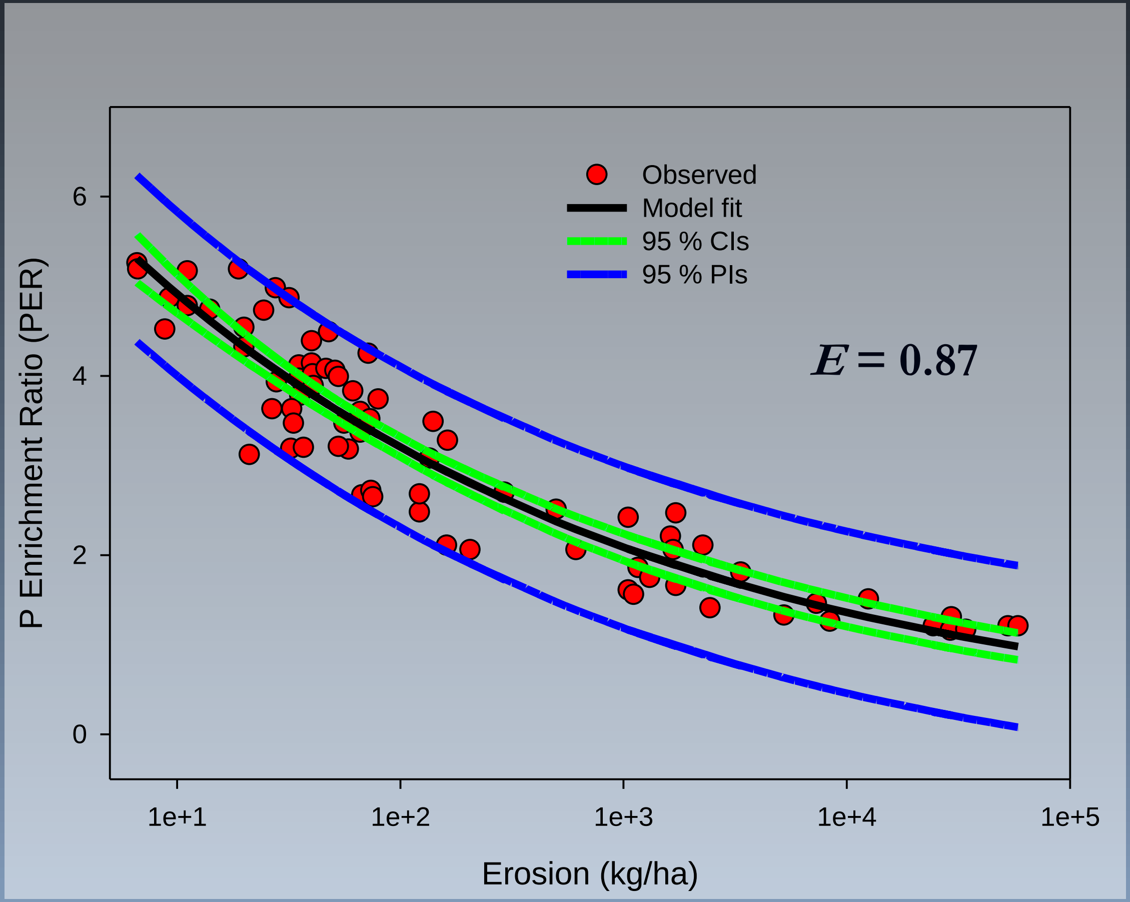


	CV
C_1	4.3%
C_2	5.7%

CI	± 3.1 – 15 %

Data from Sharpley. 2007. *In* Radcliffe and Cabrera, eds., Modeling Phosphorus in the Environment.

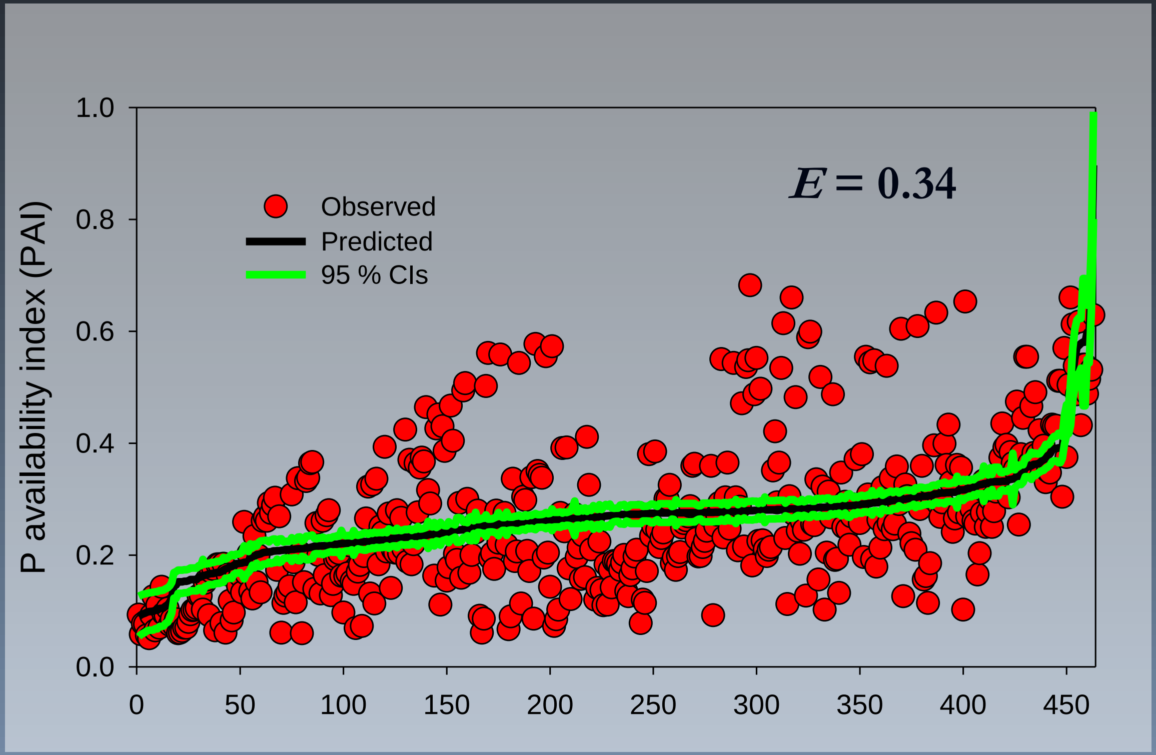
P enrichment ratio (PER) fits and uncertainties



CI	± 3.1 – 15 %
PI	± 17 – 92 %

Data from Sharpley. 2007. *In* Radcliffe and Cabrera, eds., Modeling Phosphorus in the Environment.

P availability index (PAI) fits and uncertainties

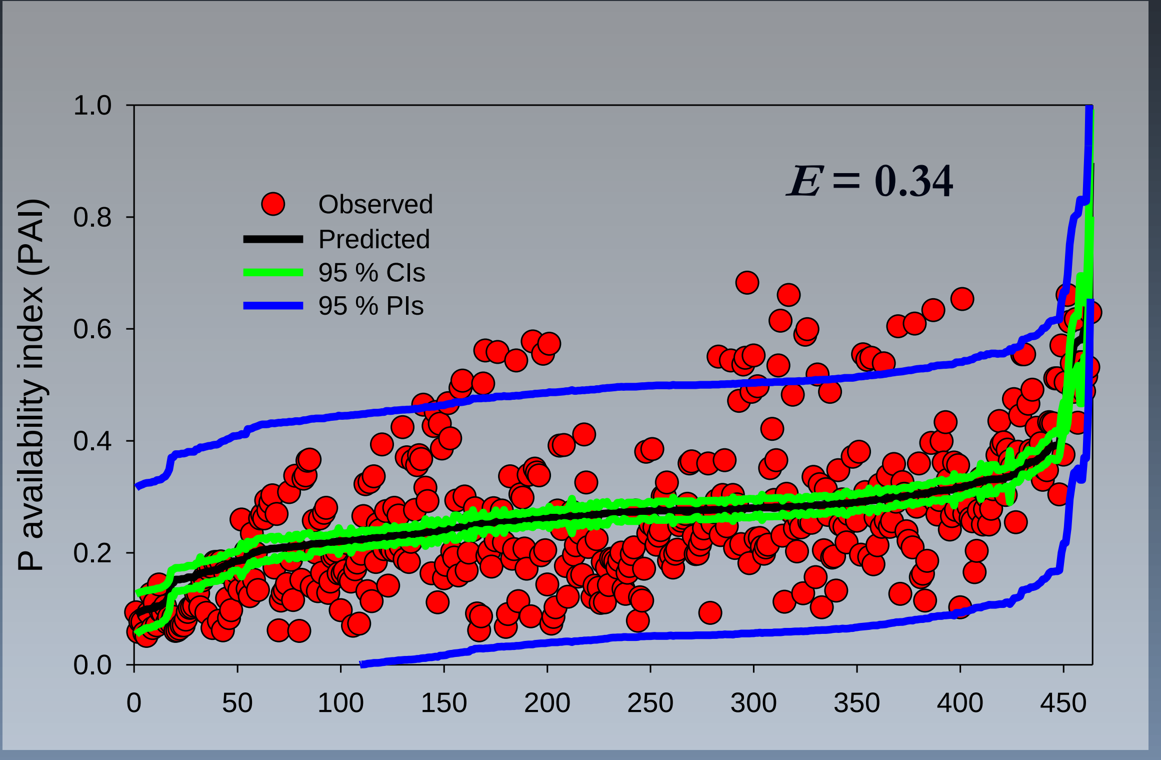


	CV
C_3	16%
C_4	15%
C_5	7.2%
C_6	5.9%

CI	± 3.9 – 40 %

Data from Vadas and White. 2010. TASABE 53: 1469-1476.

P availability index (PAI) fits and uncertainties

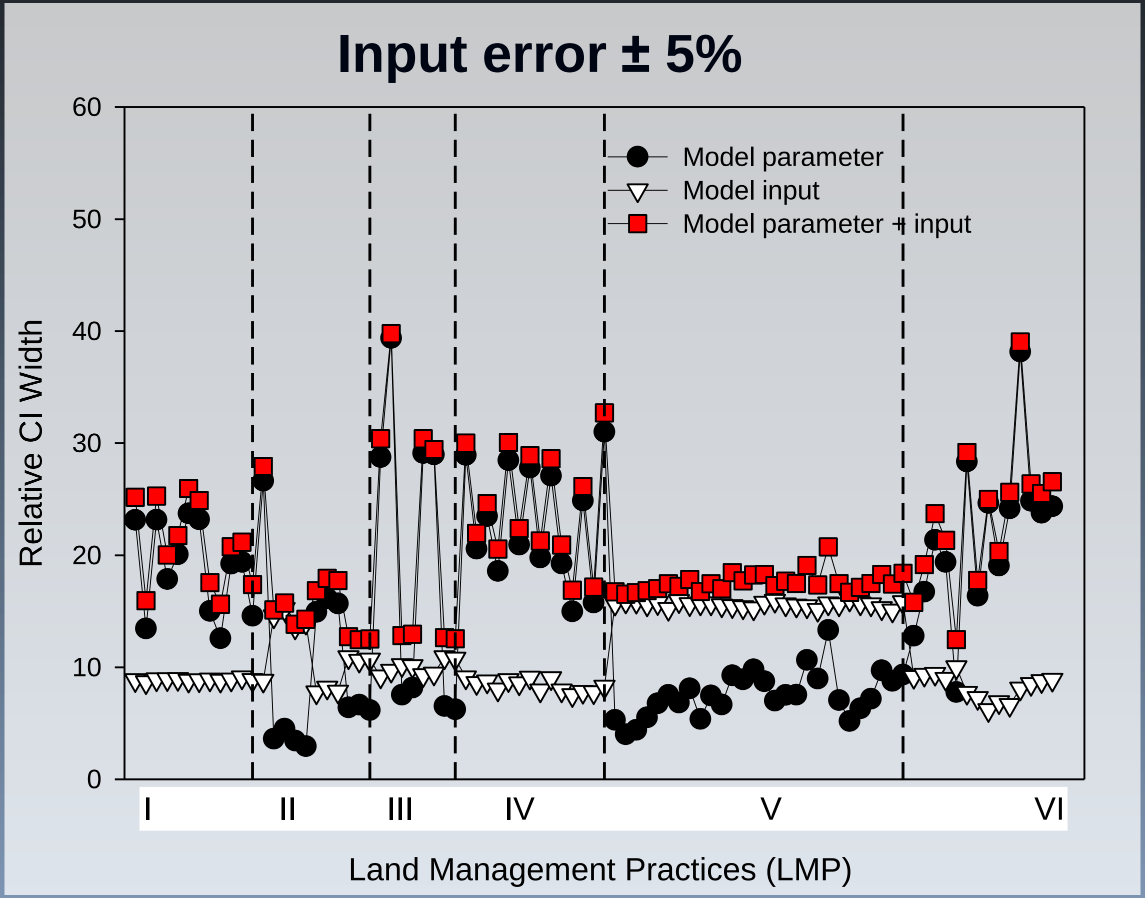


CI	± 3.9 – 40 %
PI	± 25 – 250 %

Data from Vadas and White. 2010. TASABE 53: 1469-1476.

Results: Objective 2

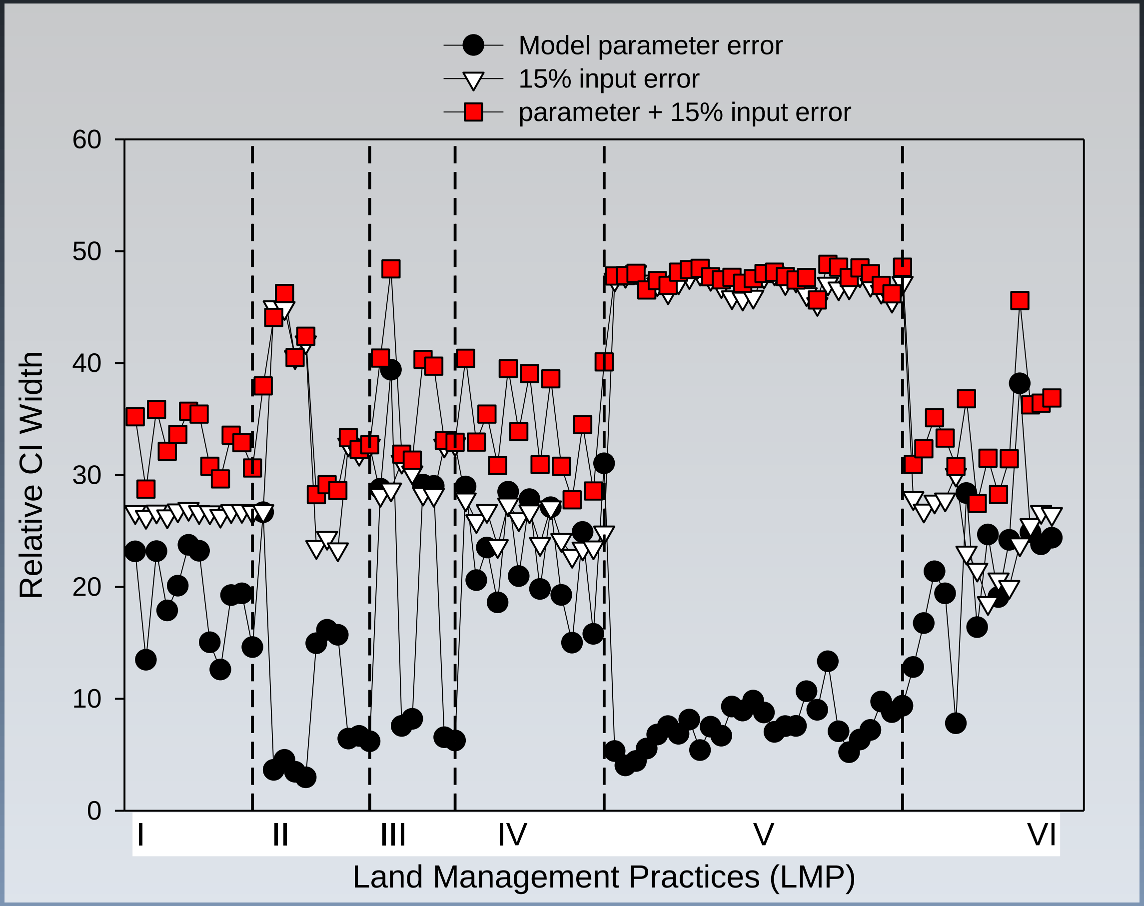
Contribution of model parameter and input error



I) no P applied
II) inorganic fertilizer,
III) manure to fields w/o erosion
IV) manure to fields with erosion,
V) fertilizer and manure to fields w/o erosion
VI) fertilizer and manure to fields with erosion.

Contribution of model parameter and input error

Input error ± 15%



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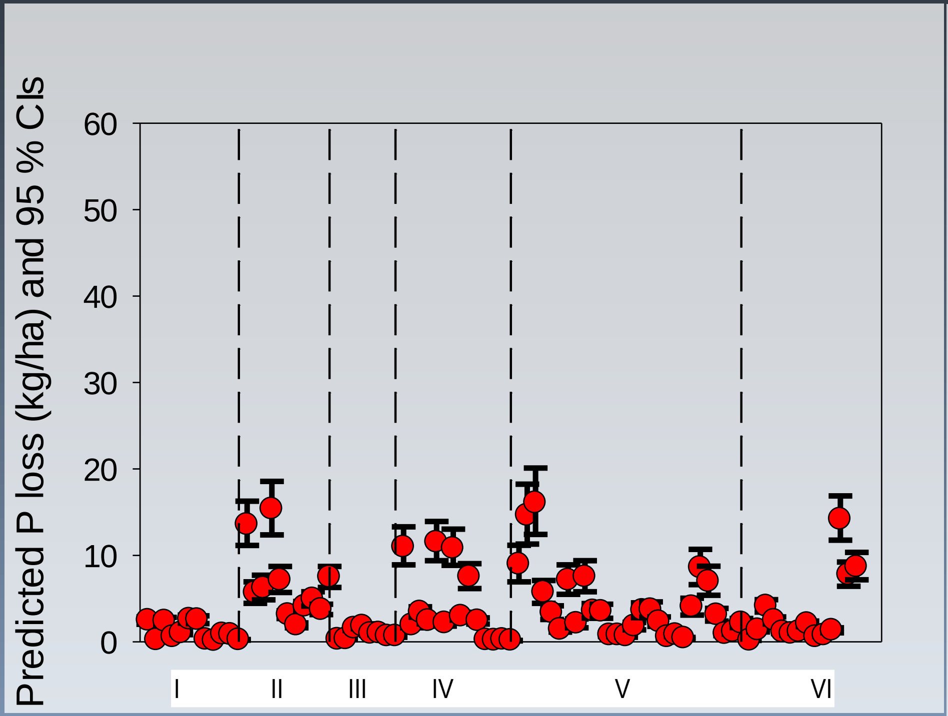
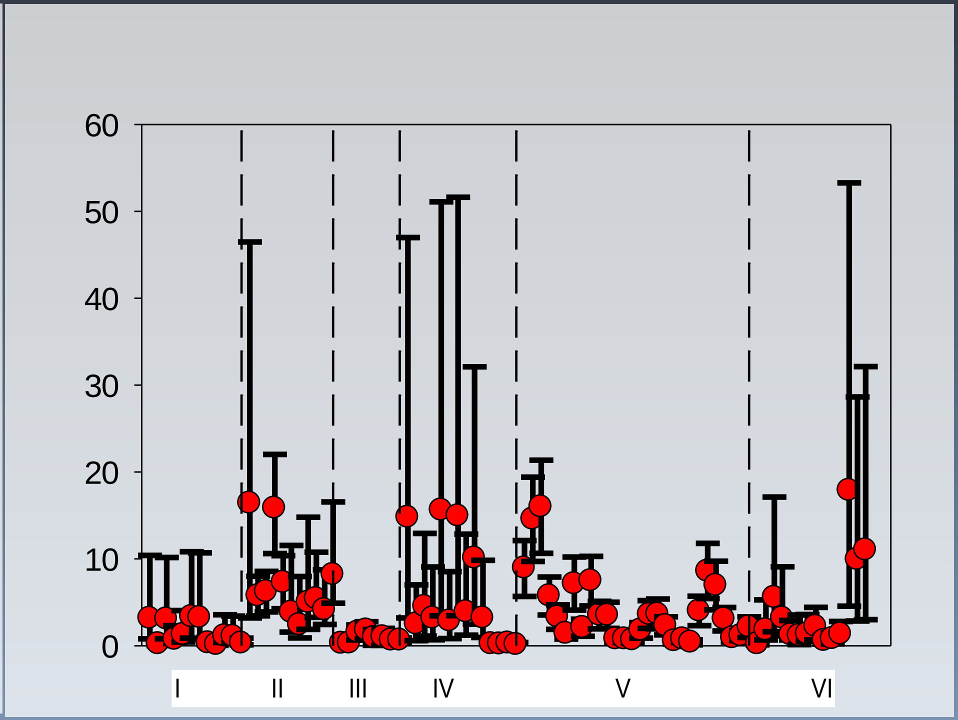
Model prediction uncertainties

Input error ± 15% + 95 % CIs



95 % PIs



Conclusions

- Uncertainties in model predictions are a fact of life
  - Ignoring them may do more harm than good
- Uncertainties in model predictions can help us better evaluate our models
- As modelers it is our responsibility to faithfully present the limitations with our model predictions to our audience
- "Doubt is not a pleasant condition, but certainty is absurd." VOLTAIRE

Questions?

This research was conducted as part of USDA-ARS National Program 214: Agricultural and Industrial By-Products

APLE model equations

$$DP_{soil} = C_7 \cdot LP \cdot RO \cdot 0.1$$

RO is annual runoff

APLE model equations

$$DP_{fert} = P_F \cdot (RO/PT) \cdot PD_F$$

$$PD_F = C_8 \cdot \exp[C_9 \cdot (RO/PT)]$$

P_F is amount of applied fertilizer

PT is annual precipitation

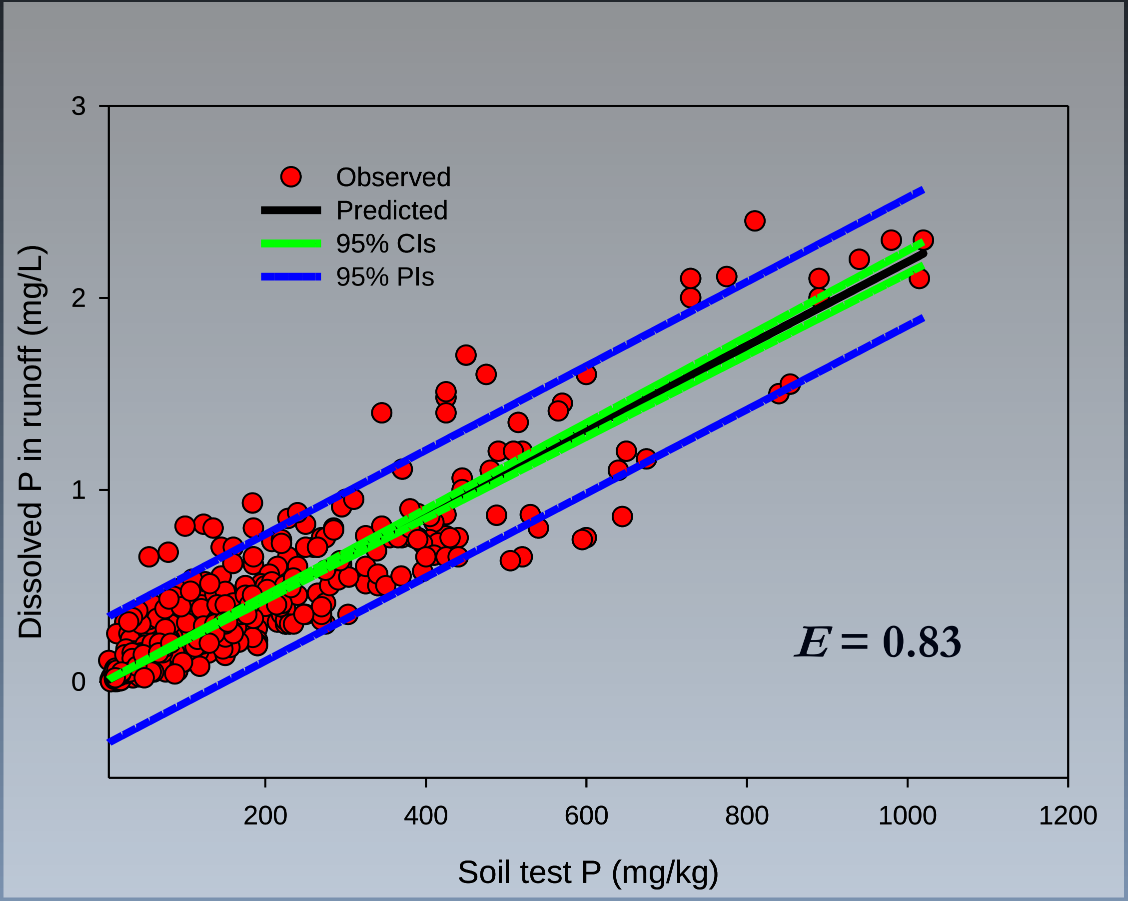
APLE model equations

$$DP_{man} = P_M \cdot (RO/PT) \cdot PD_M$$

$$PD_M = (RO/PT)^{C10}$$

P_M is amount of applied water-extractable manure

Dissolved P coefficient(DPC) fits and uncertainties

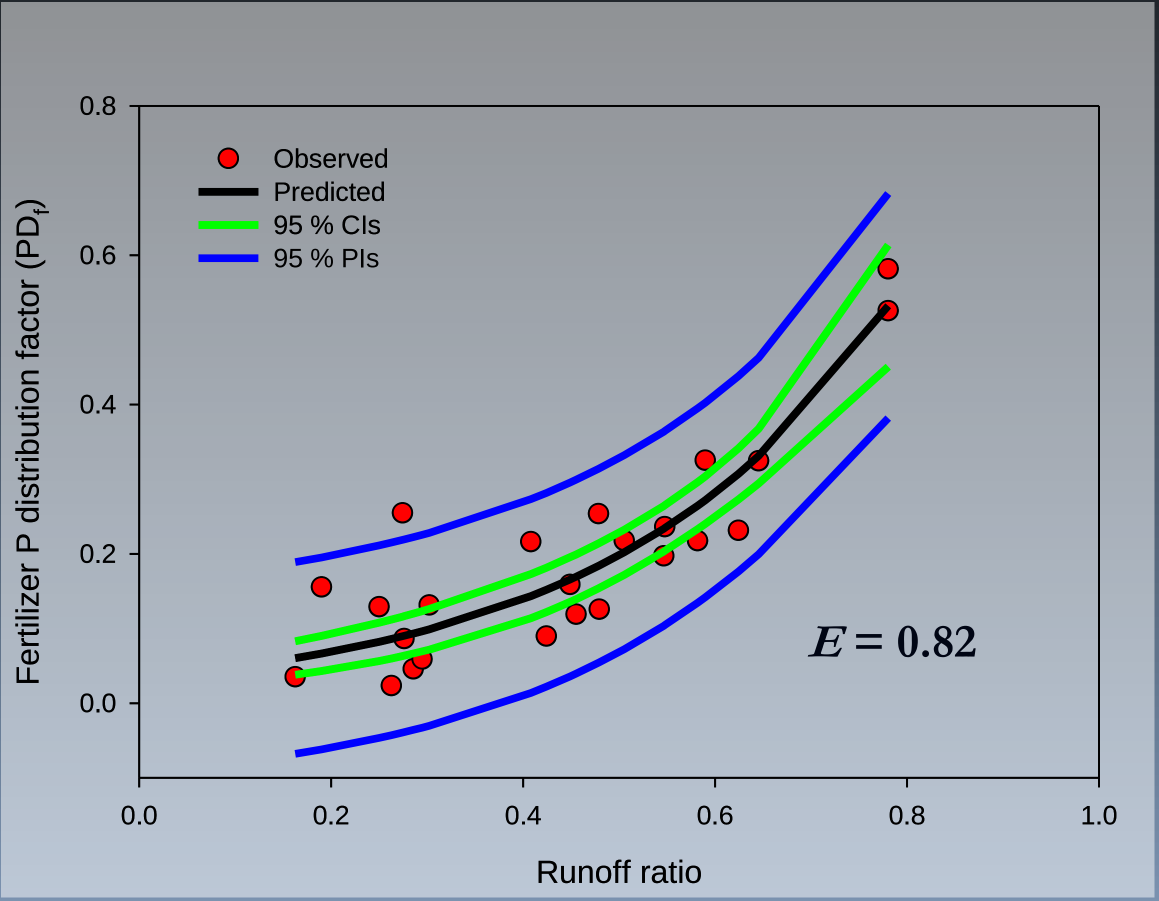


	CV
C_7	1.4%

CI	± 2.7 %
PI	± 15 – 3400 %

Data from Vadas et al. 2005. JEQ. 34: 572-580.

Fertilizer P distribution factor (PD_F) fits and uncertainties

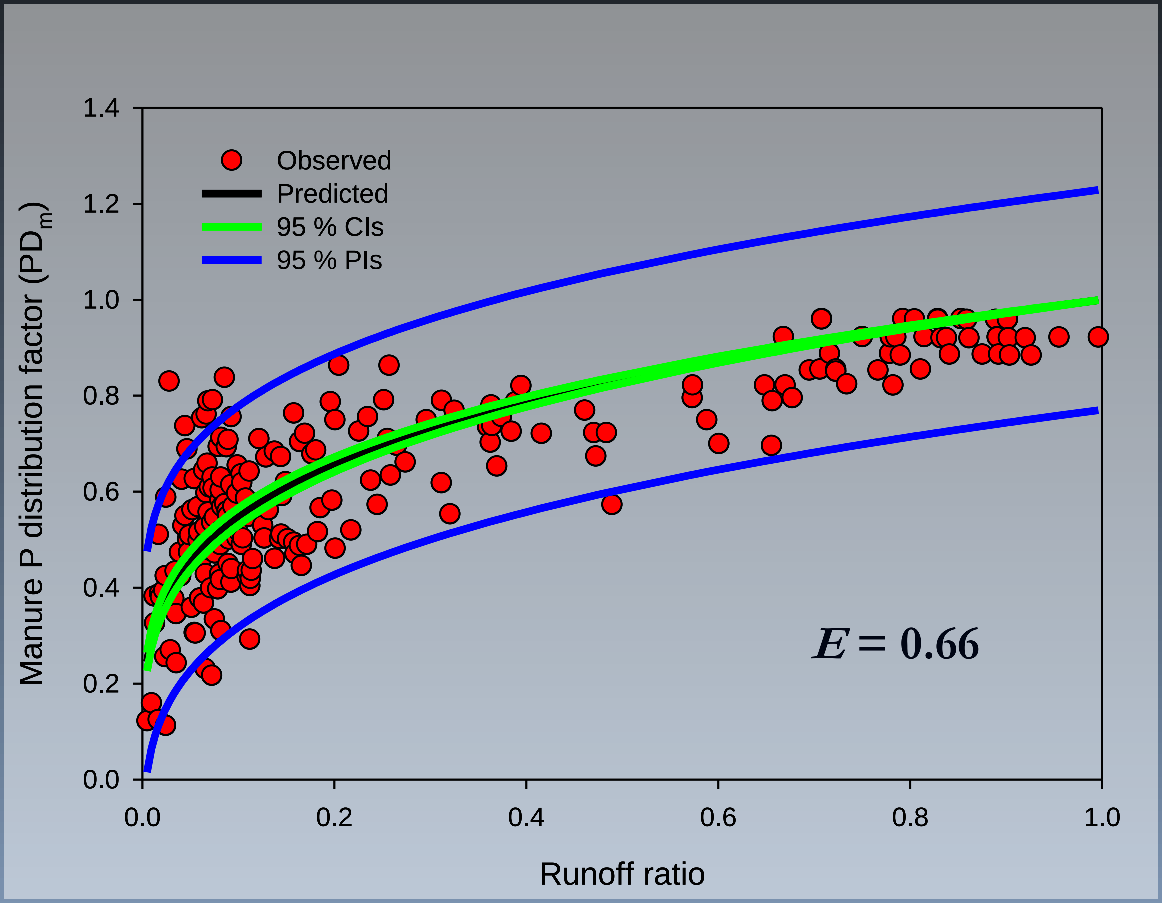


CI	± 6.0 – 37 %
PI	± 25 – 200 %

	CV
C_8	24%
C_9	10%

Data from Vadas et al. 2008. AEE. 127: 59-65.

Manure P distribution factor (PD_M) fits and uncertainties

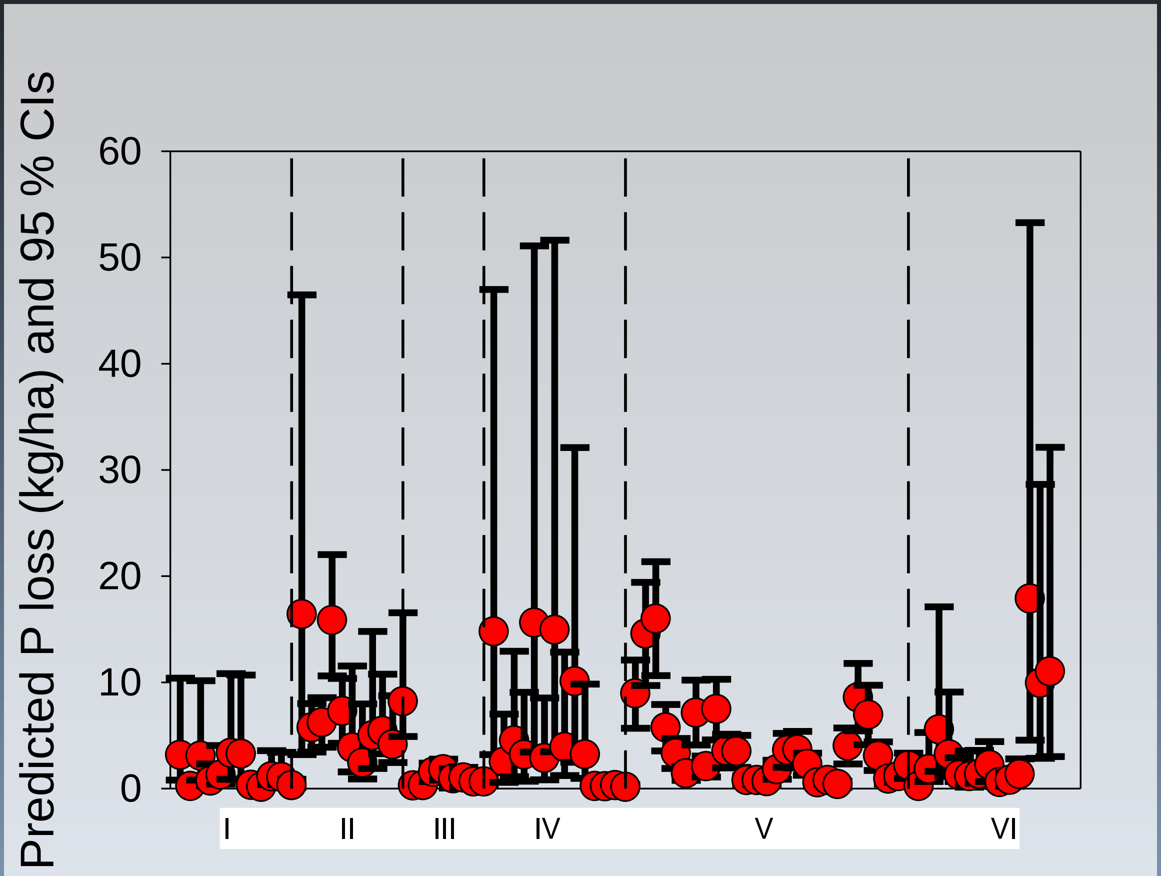


CI	± 0.01 – 7.6 %
PI	± 23 – 94 %

	CV
C_{10}	2.8%

Data from Vadas et al. 2004. JEQ. 33: 749-756.

Model prediction uncertainties



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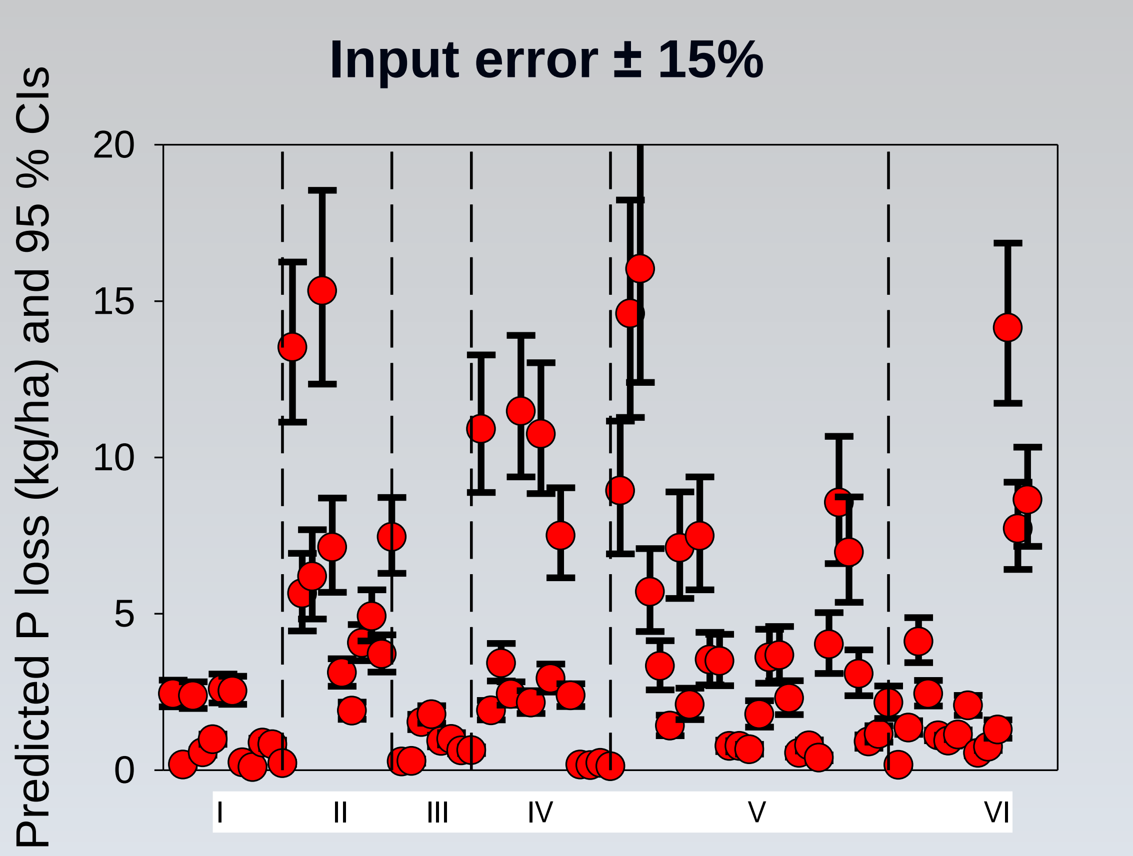

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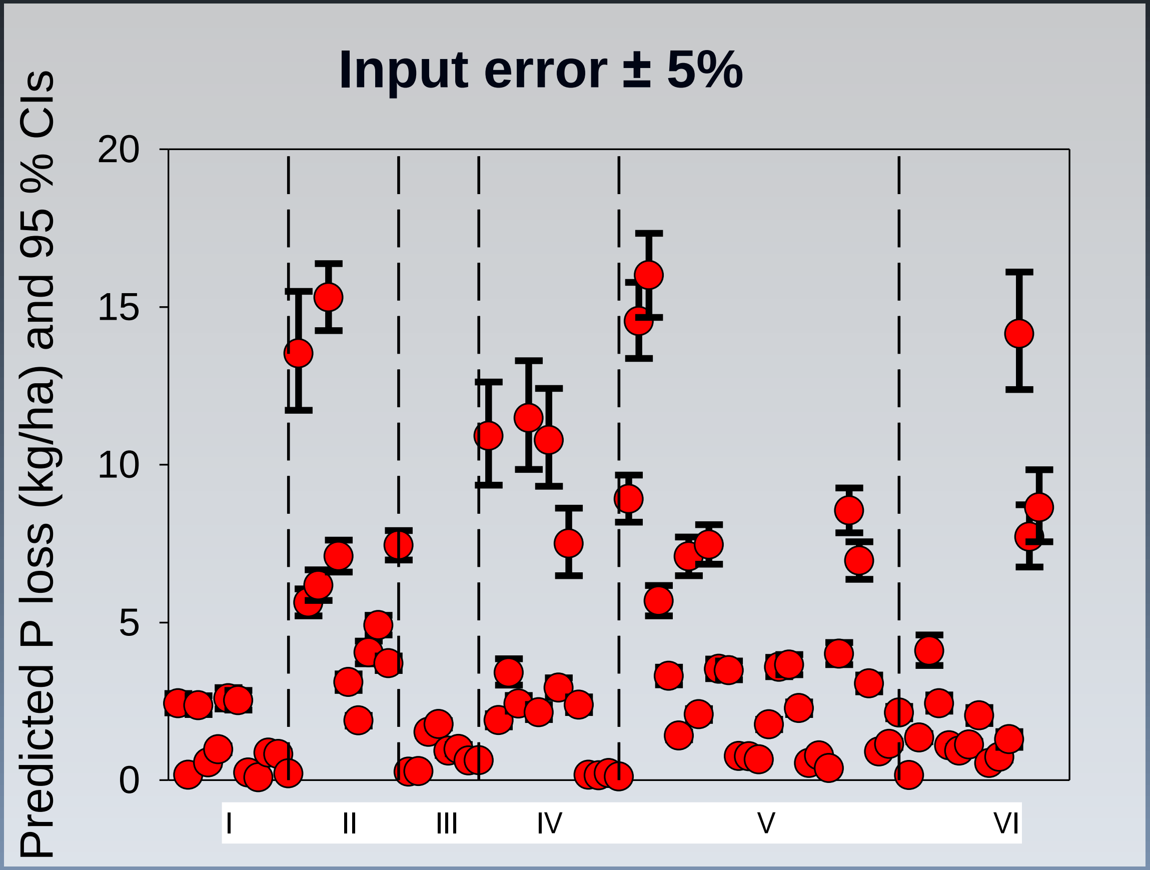
Model prediction uncertainties



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USDA ARS United States Department Of Agriculture Agricultural Research Service

U.S. Dairy Forage Research Center
Greener Horizons for Crops, Cows, and Communities

Products & Services

APLE Homepage

Annual Phosphorus Loss Estimator

***APLE** is a spreadsheet model that simulates dissolved and sediment bound phosphorus loss in surface runoff.*

Click here to download spreadsheet for
- Data Entry
- Output Graphs
- Calculations

Click here to view APLE User's Manual Version 2.0, Spring 2011

Click here to view APLE Theoretical Documentation Version 2.0, Spring 2011

For user questions or to report potential errors in calculations, contact the **APLE** creator:

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Methods: Objective 2

- Use 95 % CIs for each regression equation and calculate CIs for model predictions of P loss at field scale
- Compare uncertainties with those calculated from uncertainties associated with model input uncertainties of ± 5% and ± 15%.
  - Bolster and Vadas. 2013. JEQ. 42:1109-1118.
- Calculate 95 % CIs for predicted P loss based on prediction intervals (PIs) of the 5 regression equations