The Need for Model Uncertainty Analysis

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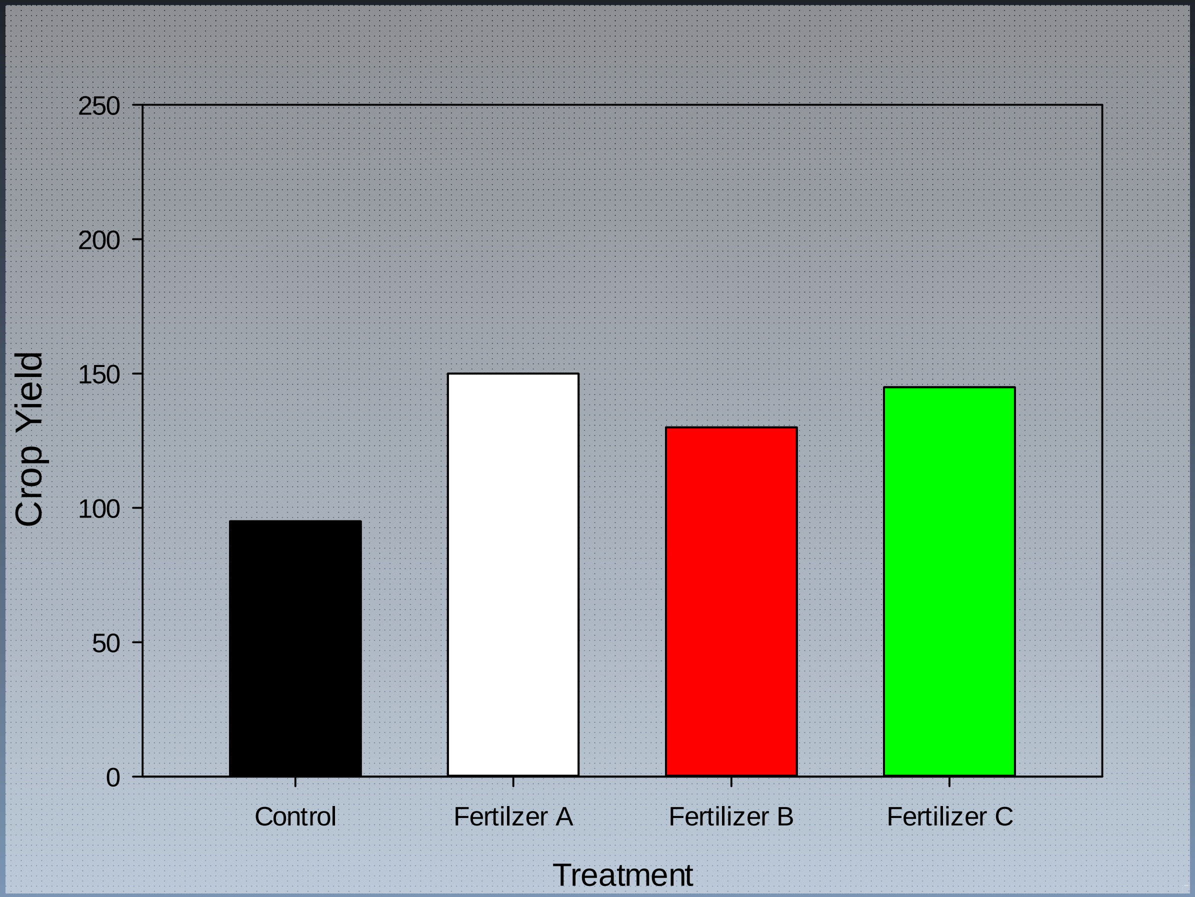
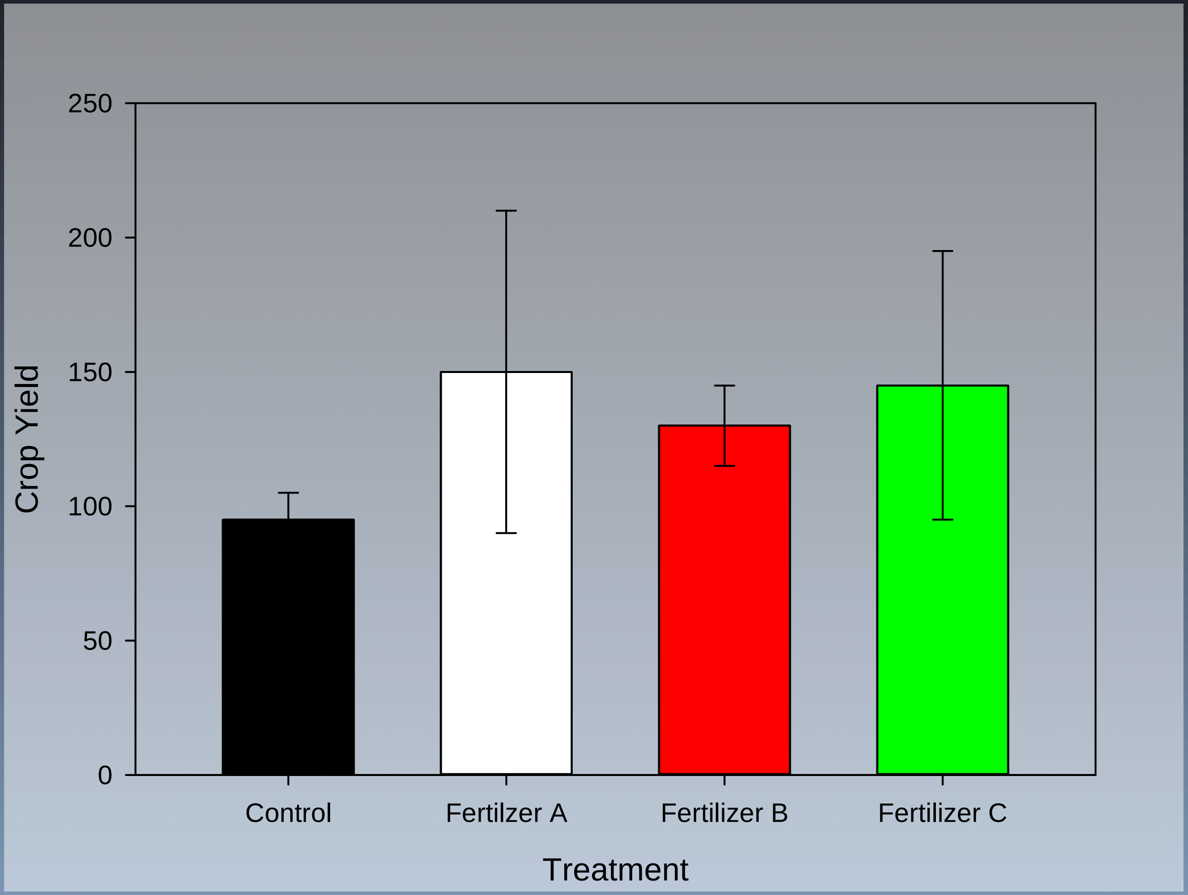

250
200
150
100
50
0
Crop Yield
Control
Fertilzer A
Fertilizer B
Fertilizer C
Treatment



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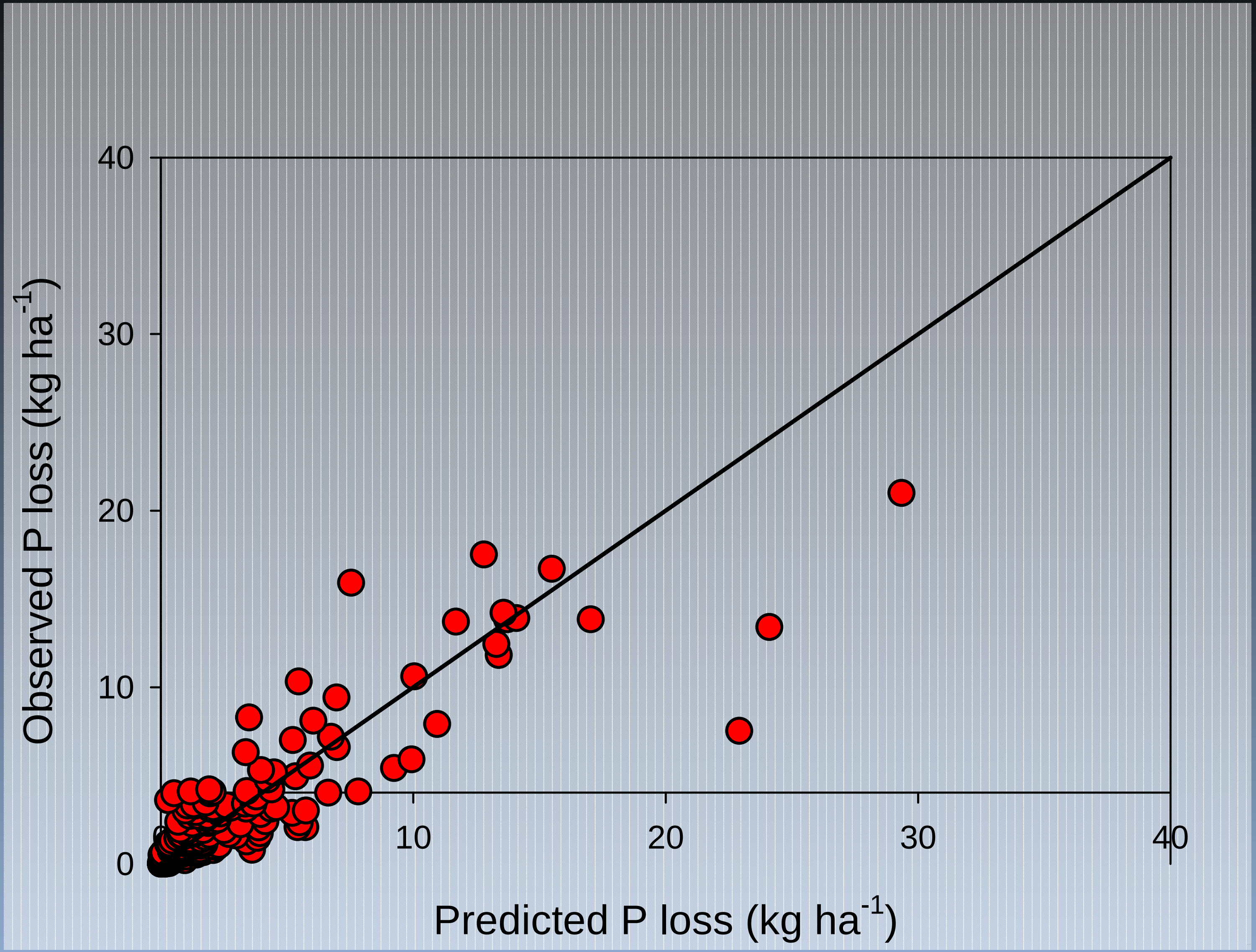
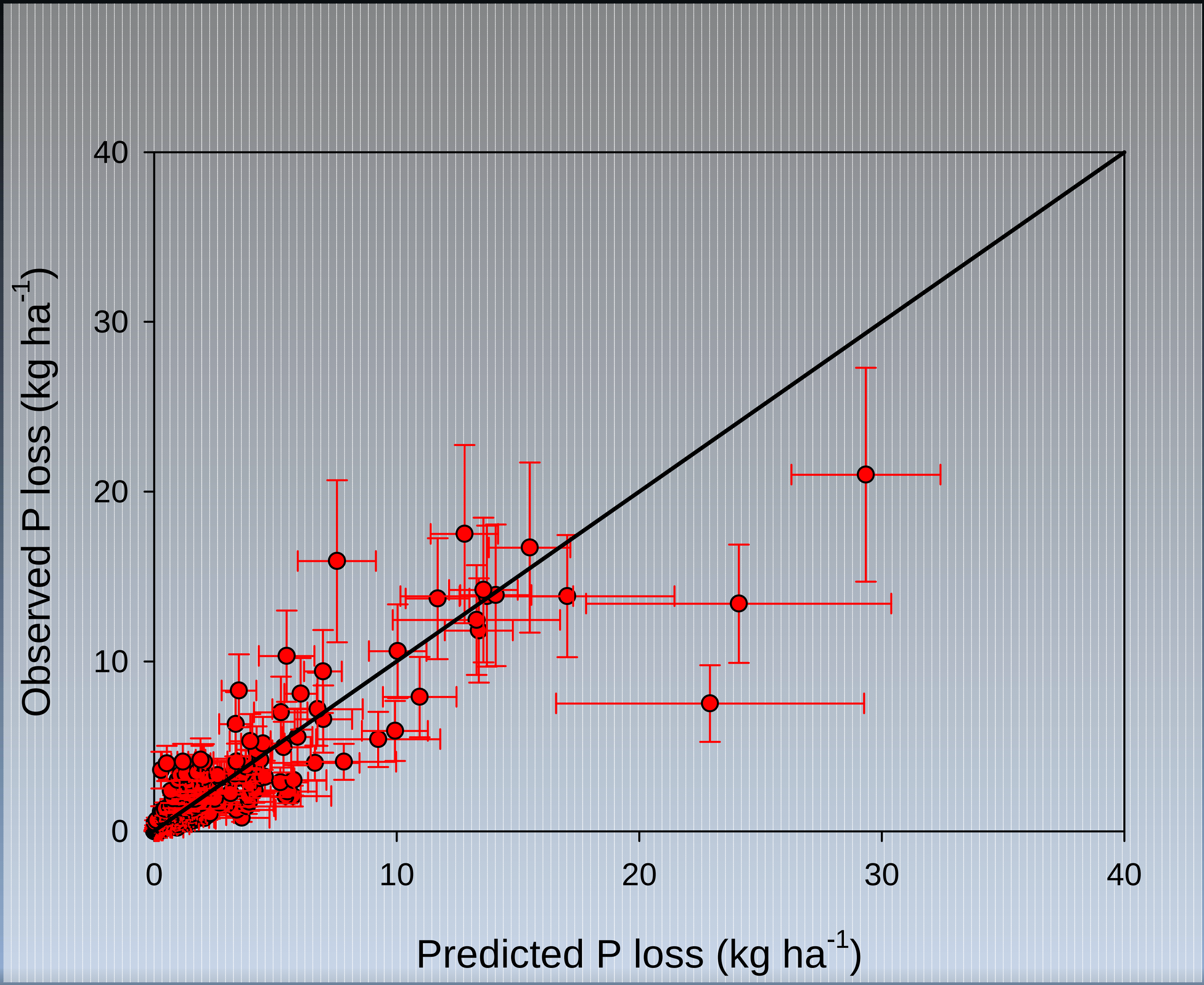


40
30
20
10
0
10
20
30
40
Observed P loss (kg ha-1)
Predicted P loss (kg ha-1)



Observed P loss (kg ha-1)
40
30
20
10
0
0
10
20
30
40
Predicted P loss (kg ha-1)

Uncertainty about uncertainties

- Hard to calculate
- Many sources…which ones to focus on?
- Lack of training/expertise/access to uncertainty analysis
- How to communicate to lay audience?
- Fear that uncertainties may undermine credibility of the model

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

Objectives

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

2. Compare relative magnitudes of parameter and model input uncertainties

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}).

APLE model equations

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

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

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

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

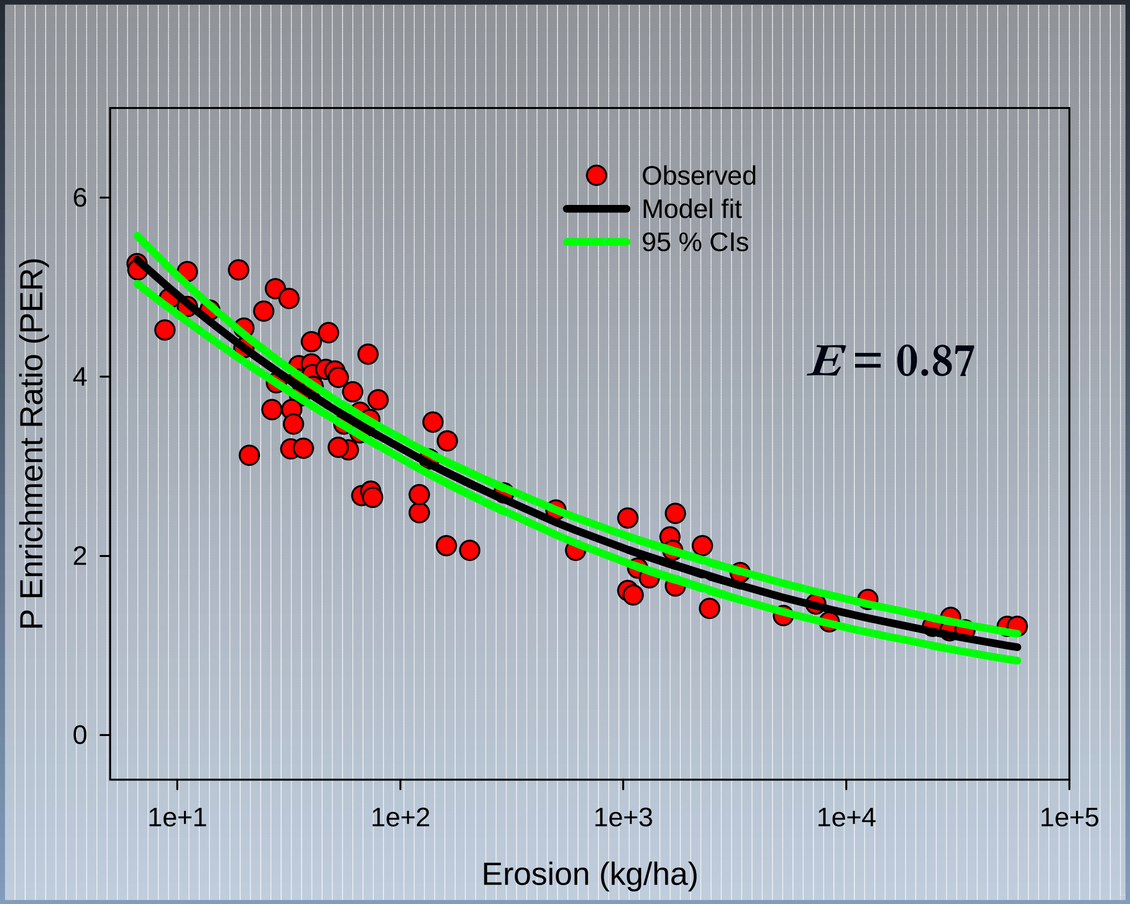
ER is the annual erosion rate (kg ha^{-1}),
PER is the P enrichment ratio
TP is total soil P (mg kg^{-1}),

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 mean response of the model
- Calculated 95 % prediction intervals
  - Accounts for parameter uncertainty AND unexplained variability
  - Used for making predictions for a single observation

P enrichment ratio (PER) fits and uncertainties

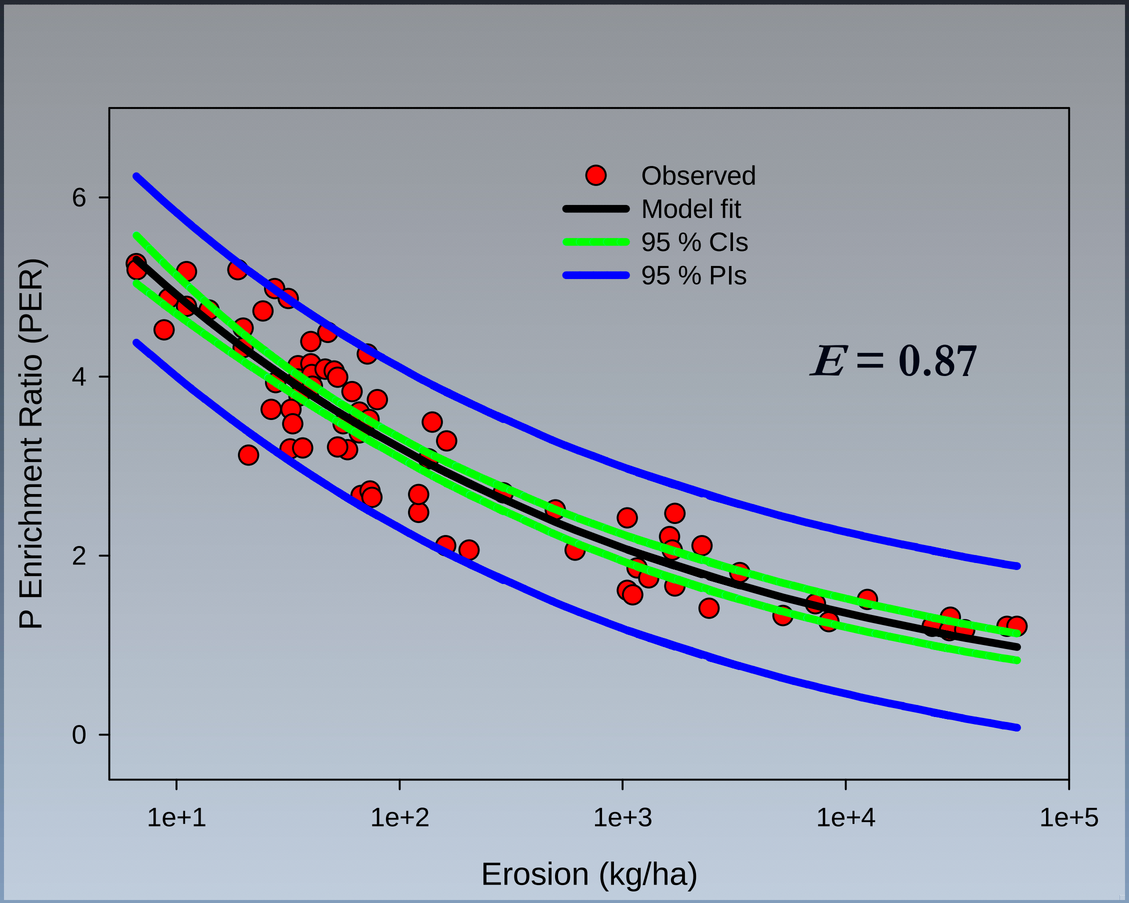


	CV
C_1	4.3%
C_2	5.7%

CI	± 3.1 – 15 %

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

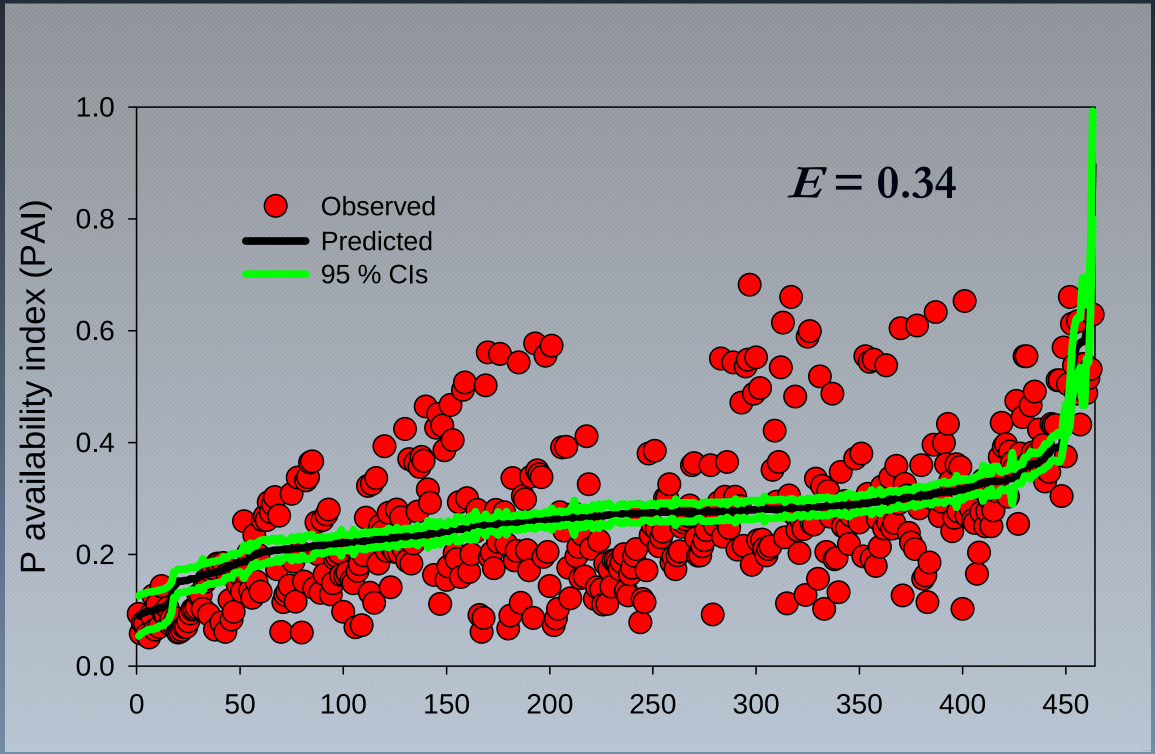
P enrichment ratio (PER) fits and uncertainties



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

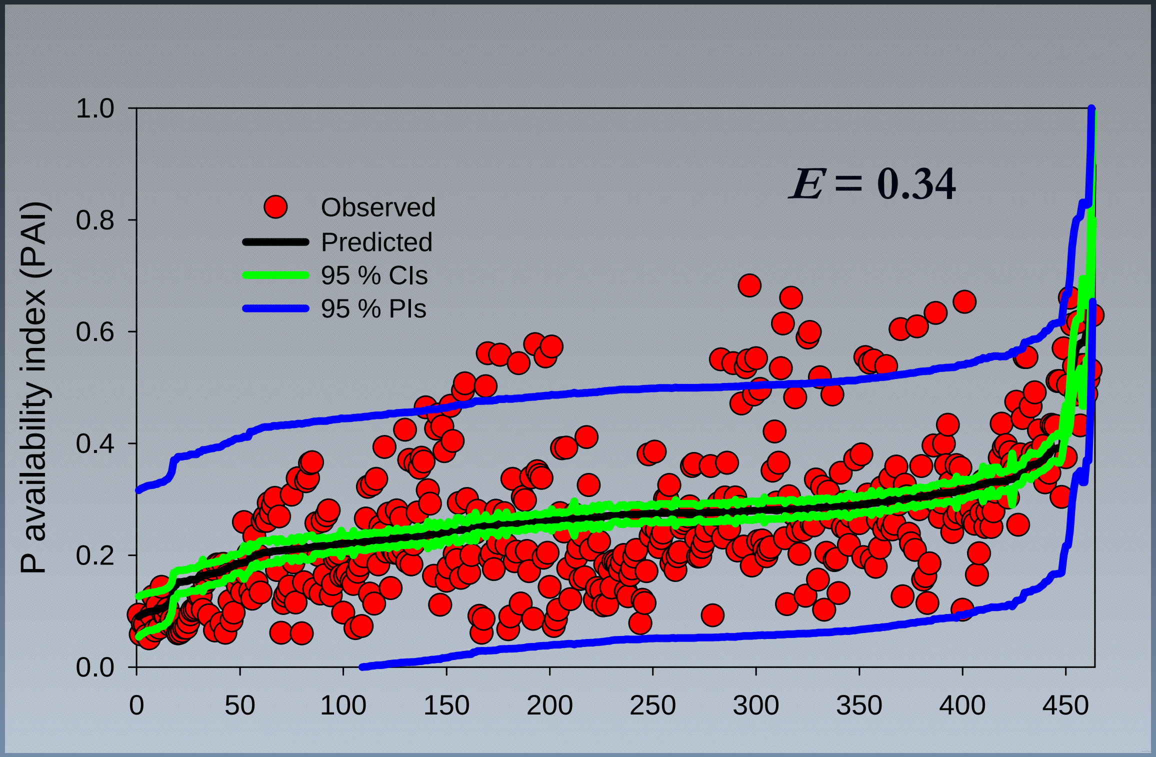


	CV
C_3	16%
C_4	15%
C_5	7.2%
C_6	5.9%

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.

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
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APLE input variables

P Loss Pathway			
DP_{man}	DP_{fert}	DP_{soil}	P_{sed}
Runoff/Precip	Runoff/Precip	Runoff	Soil Loss
Total manure applied	Total P applied	Soil Labile P	Soil Labile P
Percent manure solids	Percent fertilizer incorporation		Soil clay content
Manure TP content			Soil organic matter content
Water extractable P			
Percent manure incorporation			
Mineralization rate			

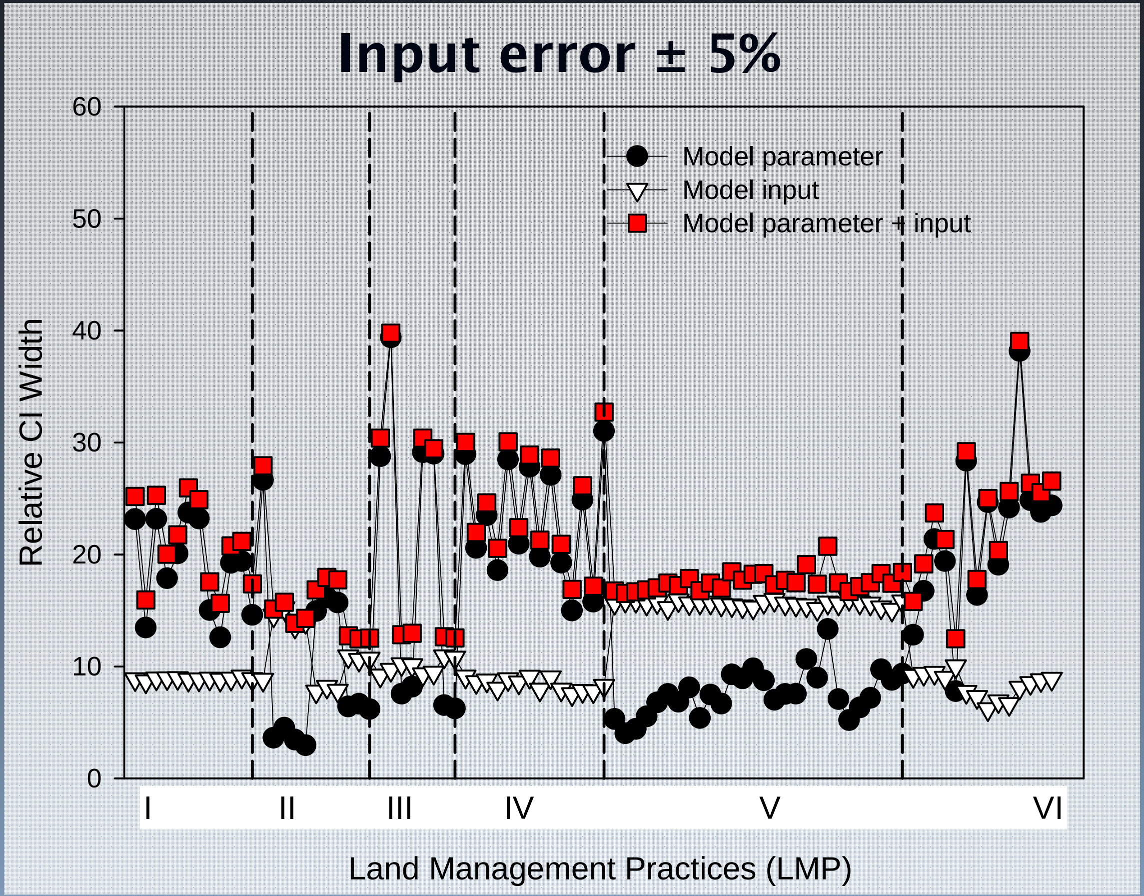
Assumed Errors in Model Input Variables

Model Variable	Small Uncertainty	Large Uncertainty
Runoff (weir)	± 5%	± 10%
Runoff (direct)	± 1%	± 3%
Erosion	± 2.5%	± 5%
Manure mineralization	± 2.5%	± 5%
P incorporation rates	± 5% (constant)	± 10% (constant)
All other variables	± 5%	± 15%

Based on Harmel et al. 2006

Results: Objective 2

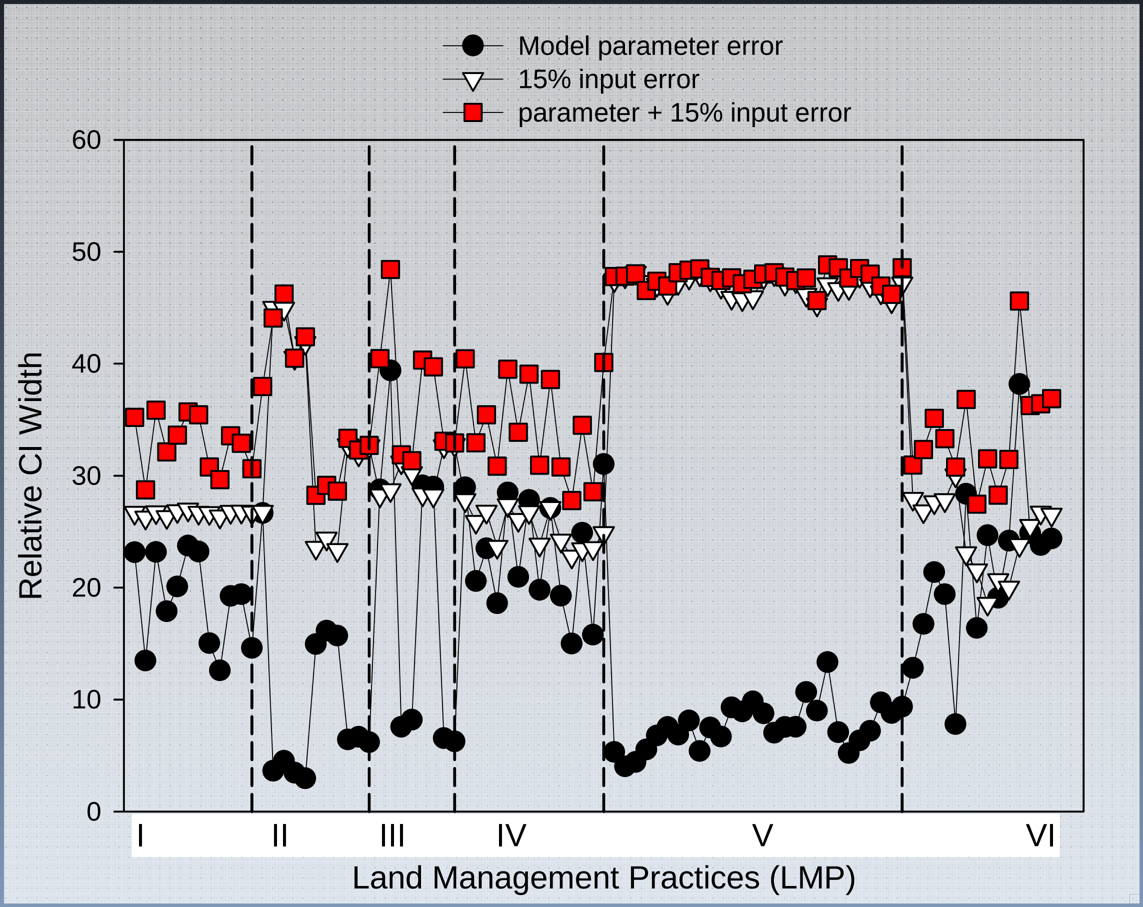
Contribution of model parameter and input error



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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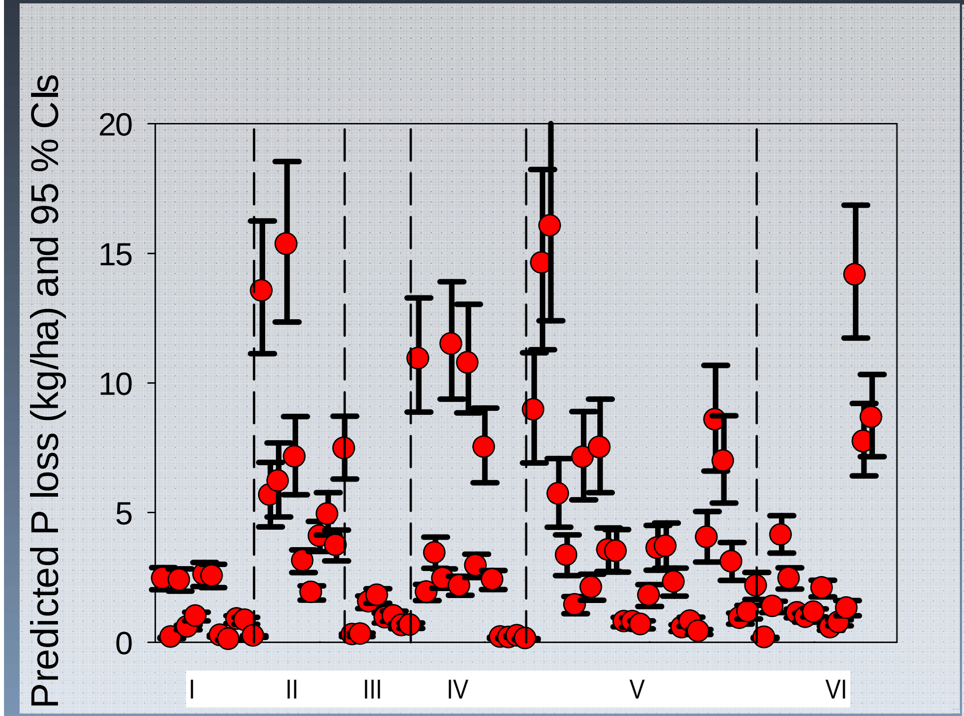
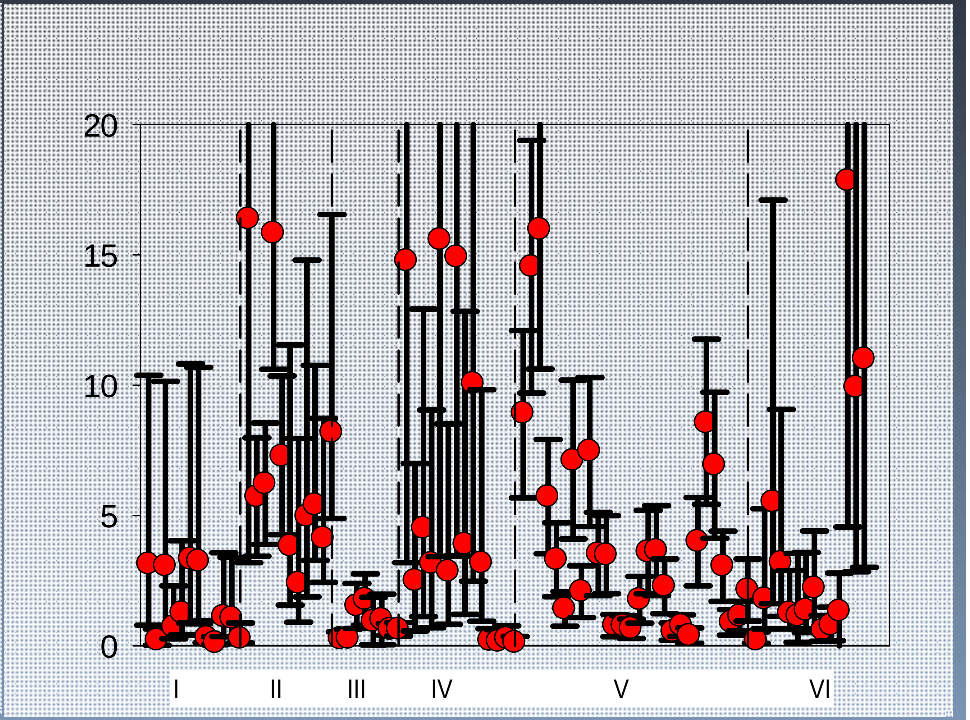
Model prediction uncertainties

Model Input + Parameter Uncertainties (95 % CIs)

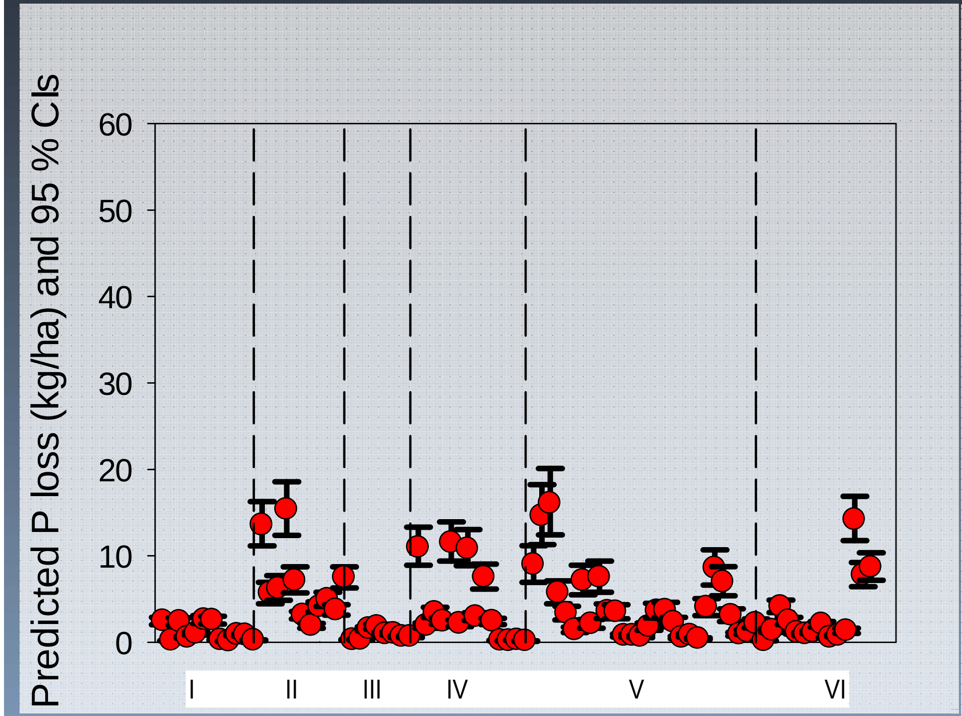


95 % PIs

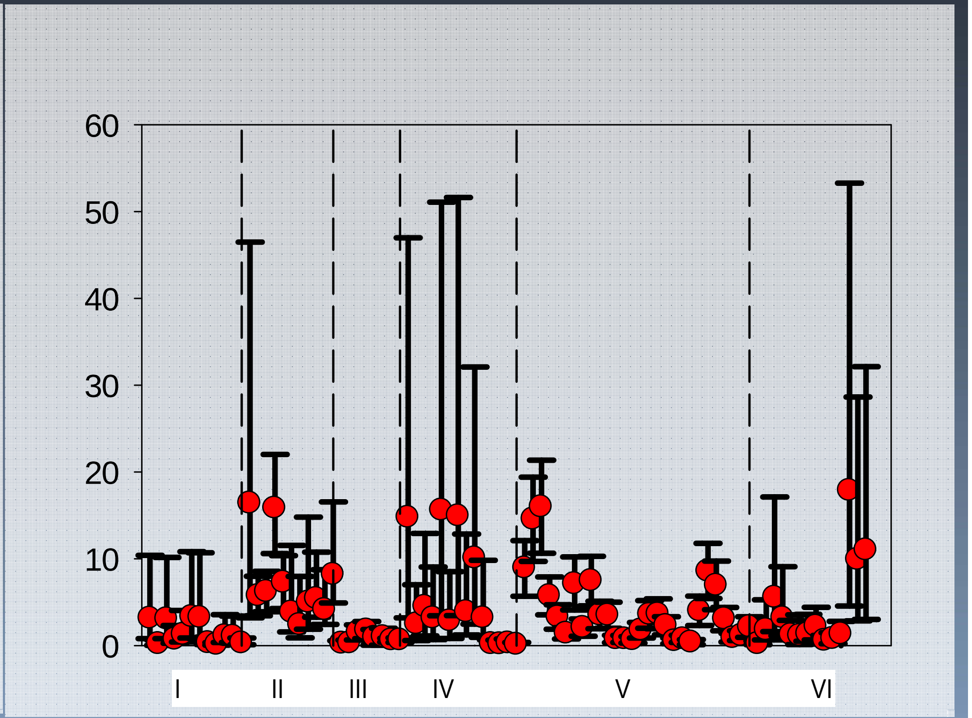


Model prediction uncertainties

Model Input + Parameter Uncertainties (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