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Biosystems and Agricultural Engineering Department

Understanding the Key Drivers for Effective Mitigation of Runoff with Vegetative Filter Strips

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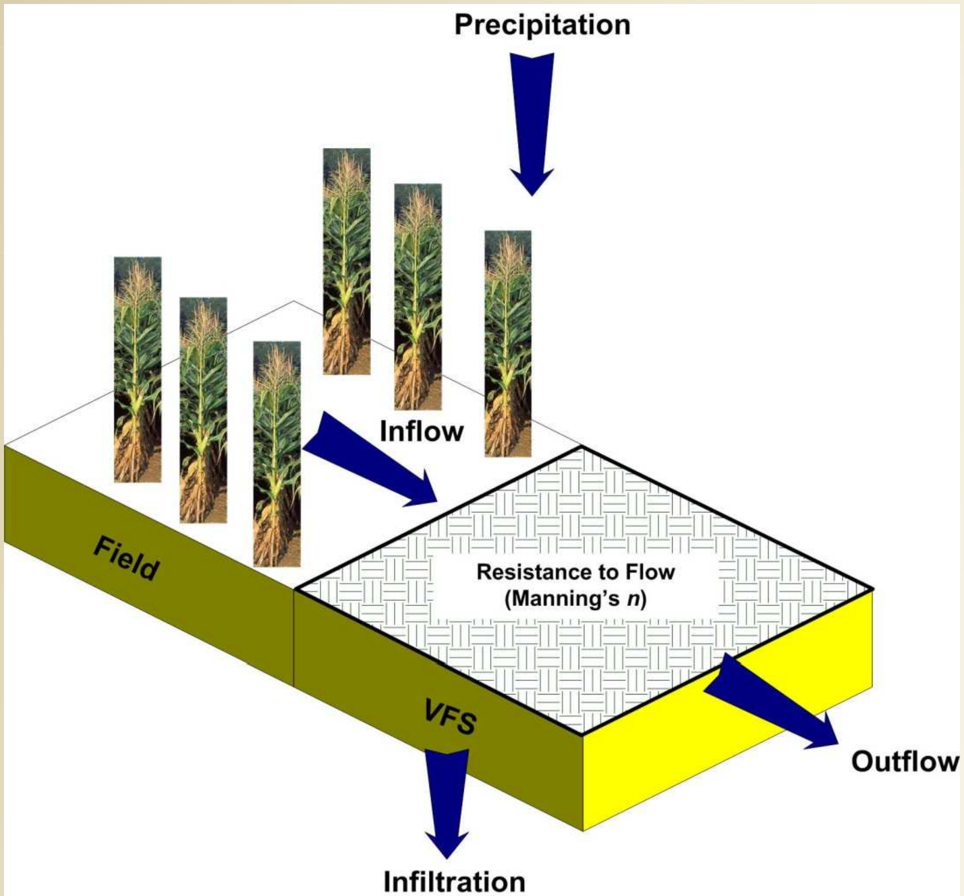
Organization of Presentation

- VFS Overview
- Key Drivers
- Prediction tools for pesticide mitigation in runoff

VFS Overview



- Retention/Detention:
  - Infiltration
  - Hydraulic Resistance
- Advantages:
  - Overland flow and dissolved pollutants reduction and delay
  - Decrease in sediment transport capacity
  - Sediment/particles deposition

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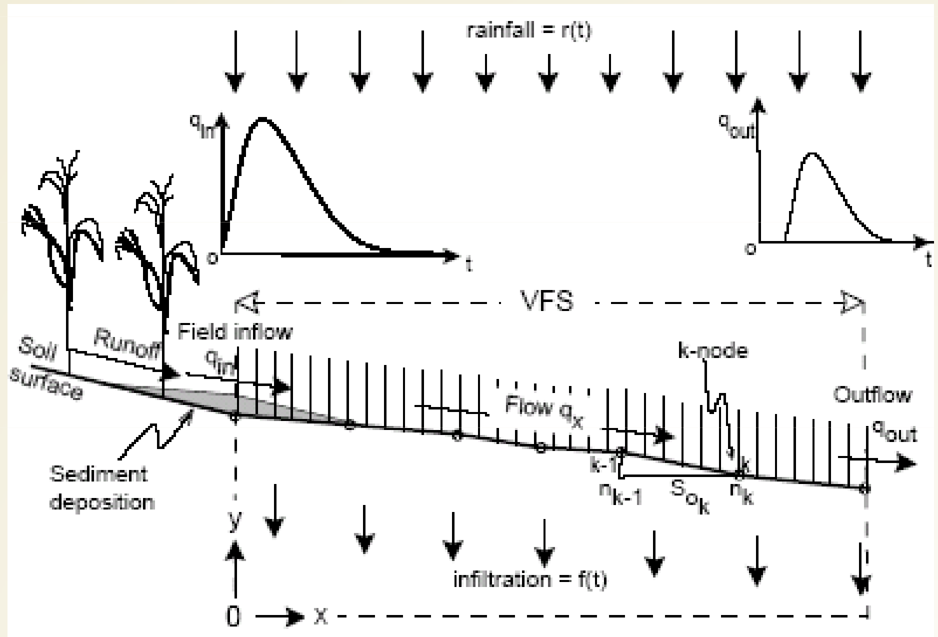
Key Drivers: Hydrologic Response

- Infiltration is governed by…
  - Soil physical properties
  - Vegetative cover
  - Antecedent moisture content
  - Rainfall intensity/Inflow
  - Slope and width
- Hydraulic resistance a function of…
  - Vegetation type and characteristics
  - Inflow volume
  - Slope and width



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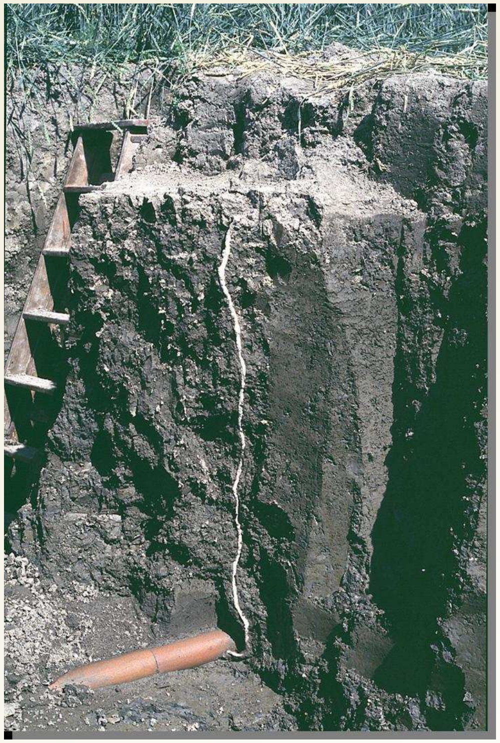
Quantifying Hydrologic Response

- Infiltration:
  - Easier to quantify for uniform infiltration into homogenous soil
  - Additional complexity with macroporosity and preferential flow
- Hydraulic Resistance/Surface Flow:
  - Easier to quantify for sheet flow
  - Additional complexity with concentrated flow/flow convergence



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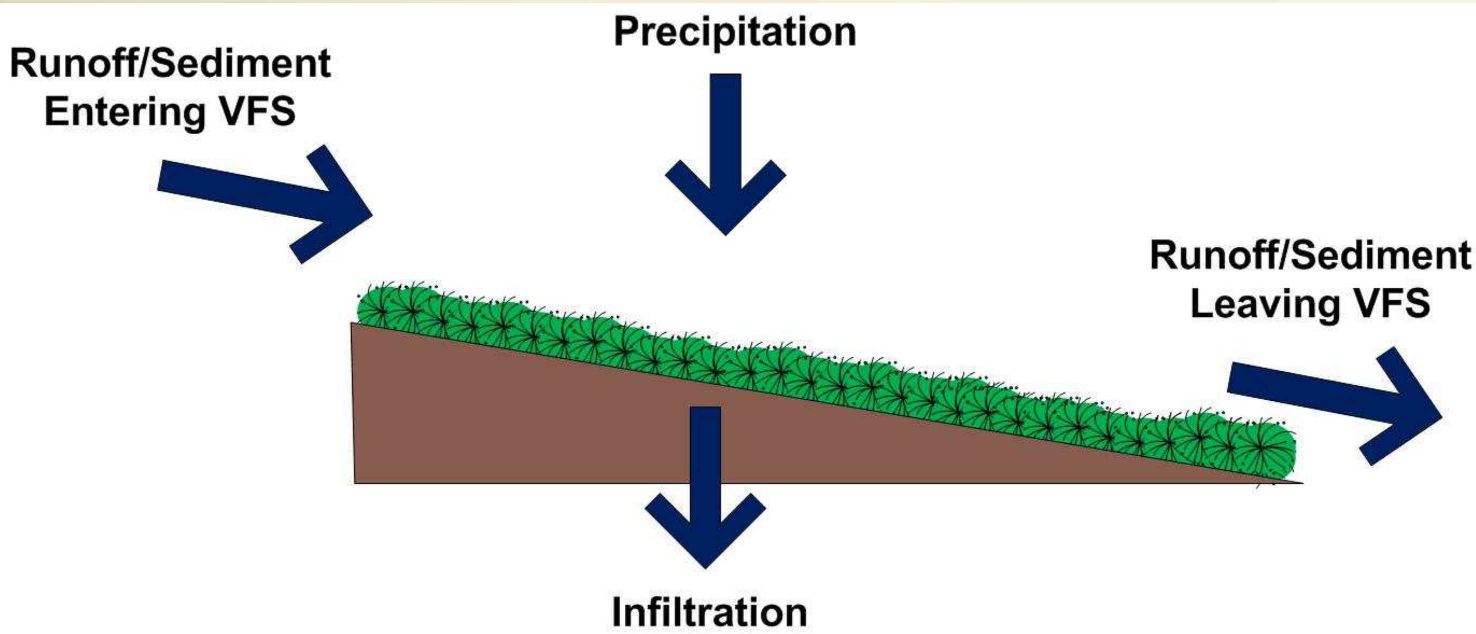
Hydrologic Drivers



ΔQ = Infiltration = (Runoff Entering + Preciptation) – Runoff Leaving

ΔE = Sedimentation = Sediment Entering – Sediment Leaving

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Key Drivers: Sediment/Contaminant

- Contaminant Property (Pesticide):
  - Phase distribution factor

$$K_d = \frac{K_{oc}(\%OC)}{100} \qquad F_{ph} = \frac{Q_i}{K_d E_i}$$

K_{oc} = organic carbon sorption coefficient

K_d = distribution coefficient

- Sediment:
  - Percent clay content of incoming sediment

Prediction Tools for Diffuse Contaminants

- Largely based on physical characteristics of the buffer system…
  - SWAT - Buffer width: $\Delta P = 0.367(W_B)^{0.2967}$
  - USDA suggests correlation between percent pesticide reduction and K_{oc}
  - Liu and others (2008) - Correlation to buffer slope and width – $R^2 = 0.23$

ΔP = Pesticide Reduction (%)

Survey of Literature

- Effectiveness of VFS compiled from 127 published journal articles
- Event-scale studies
  - 5 publications for model development
  - 5 publications for model evaluation

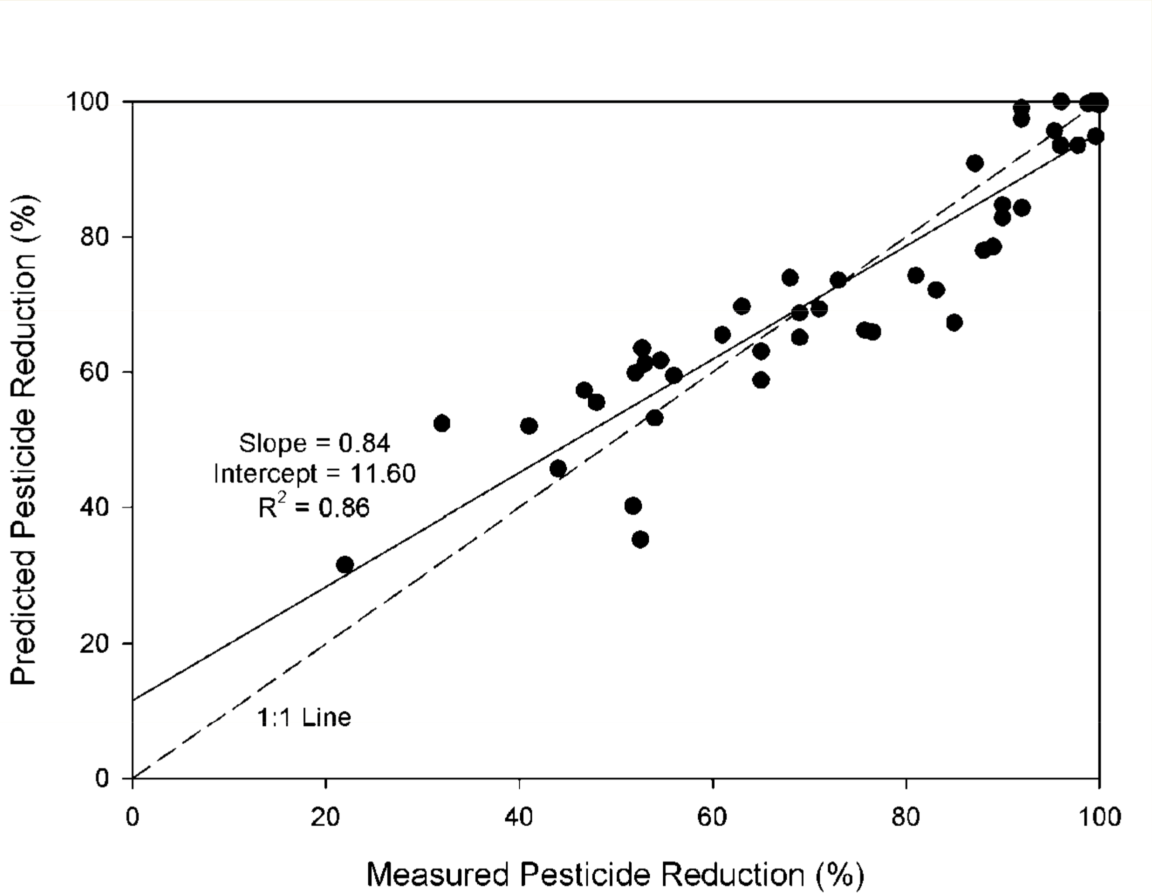
Model Development Dataset

- 47 observations: alachlor , atrazine , chlorpyrifos, metolachlor, and permethrin
- ΔP ranging from 22 to 100%
- VFS widths ranged from 3.0 to 20.1 m (VFS width in the primary direction of flow)
- Natural and simulated rainfall and runoff events
- Soils with % clay content from 21 to 30%

Model Development

$$\Delta P = f\left(\Delta Q, \Delta E, \ln\left(F_{ph} + 1\right), \%C\right)$$

- Buffer width not statistically significant predictor
- Buffer width captured by ΔQ



Model Analysis – K_{oc}

- High mobility pesticides (low K_{oc})
  - $\Delta \boldsymbol{Q}$ - Infiltration
- Low mobility pesticides (high K_{oc})
  - $\Delta \boldsymbol{E}, \boldsymbol{F_{ph}}$ – Sedimentation, Phase Distribution Factor

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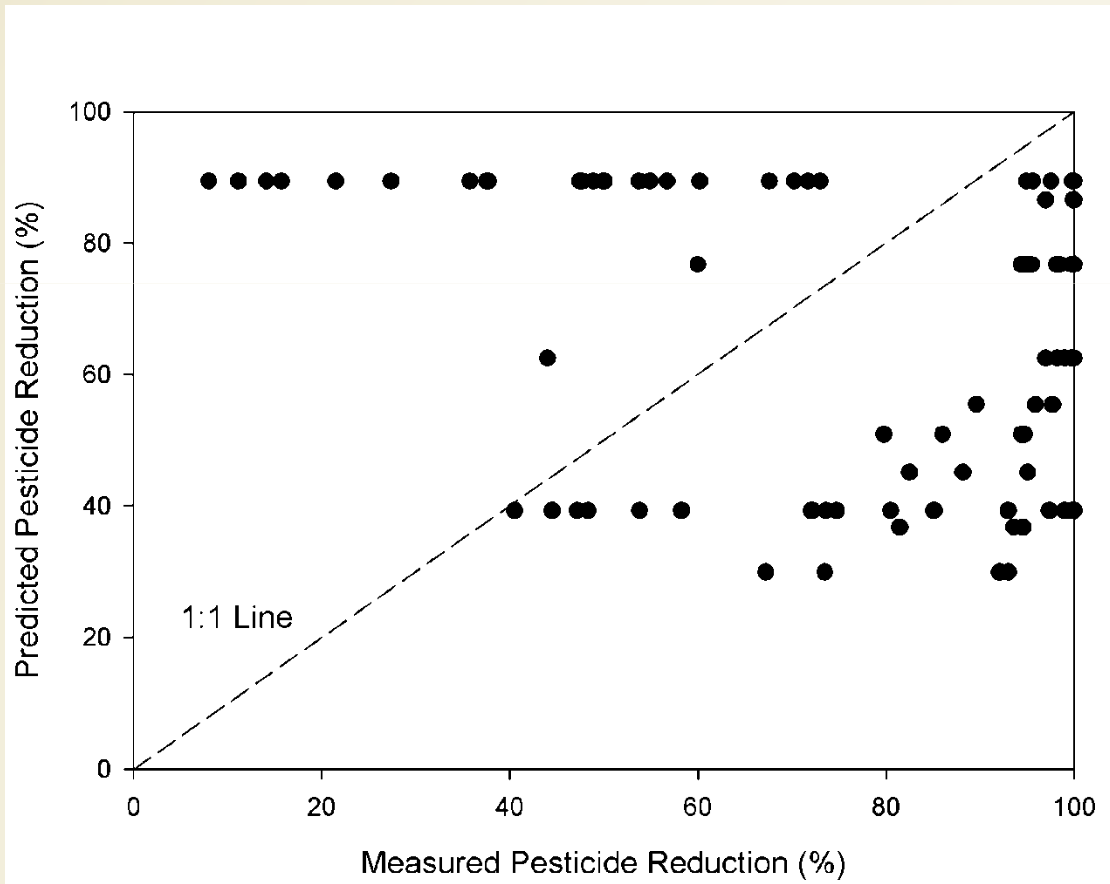
Model Evaluation Dataset

- 120 measured ΔP ranging from 8.0 to 100%
- Atrazine, cyanazine, diflufenican, isoproturon, lindane, metolachlor, metribuzin, pendimethalin, and terbuthylazine
- VFS widths ranged from 0.5 to 20.1 m
- Soils with % clay content from 12 to 45%

Buffer Width Equation (SWAT)

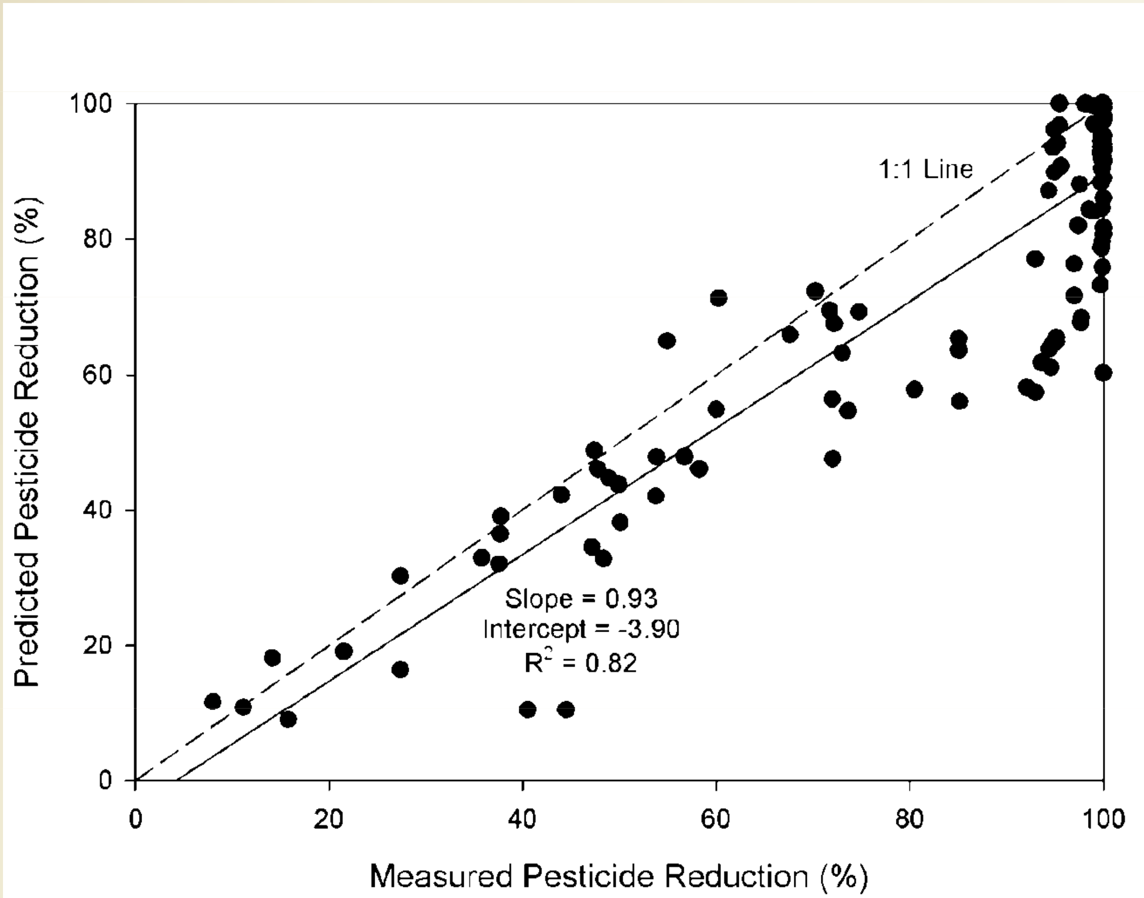
- Does not adequately predict VFS efficiency by itself

$$\Delta P = 0.367\left(W_B\right)^{0.2967}$$



Model Evaluation

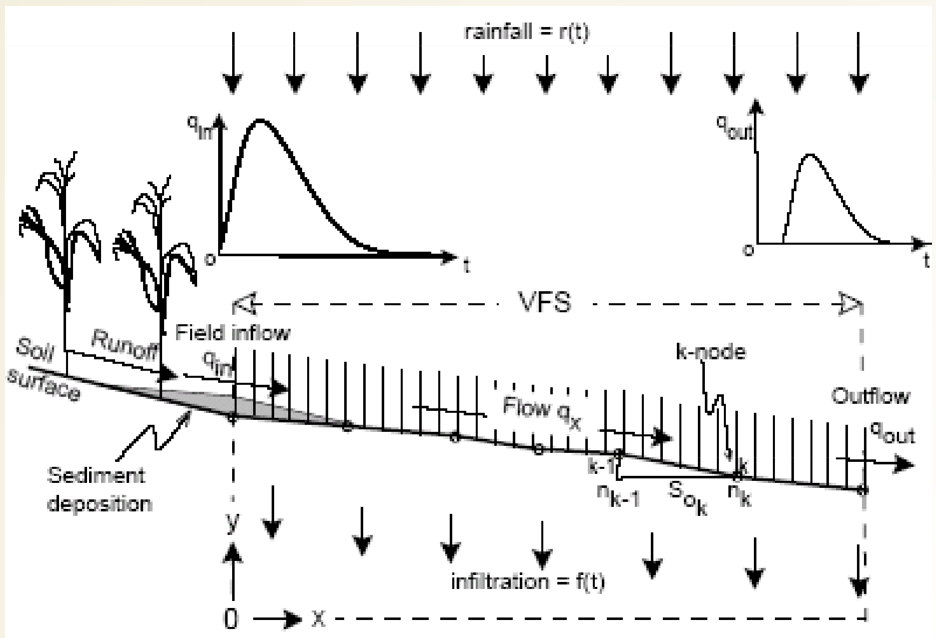
- Improved prediction capability by accounting for hydrologic response



Use of Empirical Equations

- Parameters for estimating ΔP, such as ΔQ and ΔE, not easily predicted
- Uncalibrated VFS model that predicts ΔQ and ΔE
  - Vegetative Filter Strip Modeling System, VFSMOD
  - Finite-element, field-scale, storm-based model

- Routes incoming hydrograph and sedigraph
- Infiltration - Green-Ampt
- Sediment trapping - GRASSF



VFSMOD Critical Parameters

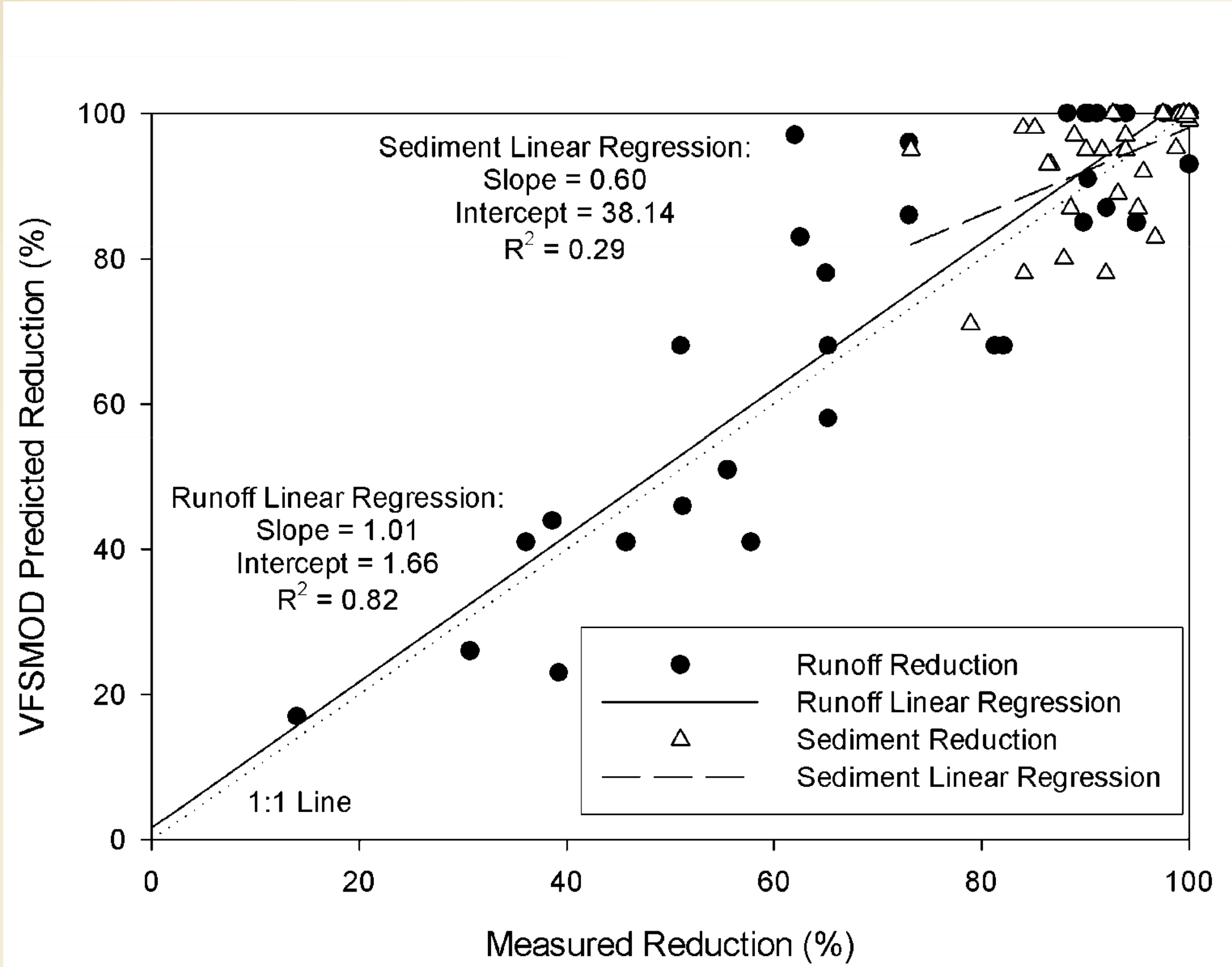
- Soil Hydraulic Parameters (K_{sat}, θ_o and θ_s)
  - Impacts infiltration
- Roughness Coefficient (Manning's *n*)
  - Impacts hydraulic resistance
  - Impacts timing of the peak runoff and not the total runoff volume
  - Default values of Manning's *n* for closest vegetation type

VFSMOD Critical Parameters

- Rainfall volume and duration and entering runoff volume and duration
- Concentration of sediment in the entering runoff (C_s)
- Characteristics of the sediment
- Characteristics of the VFS

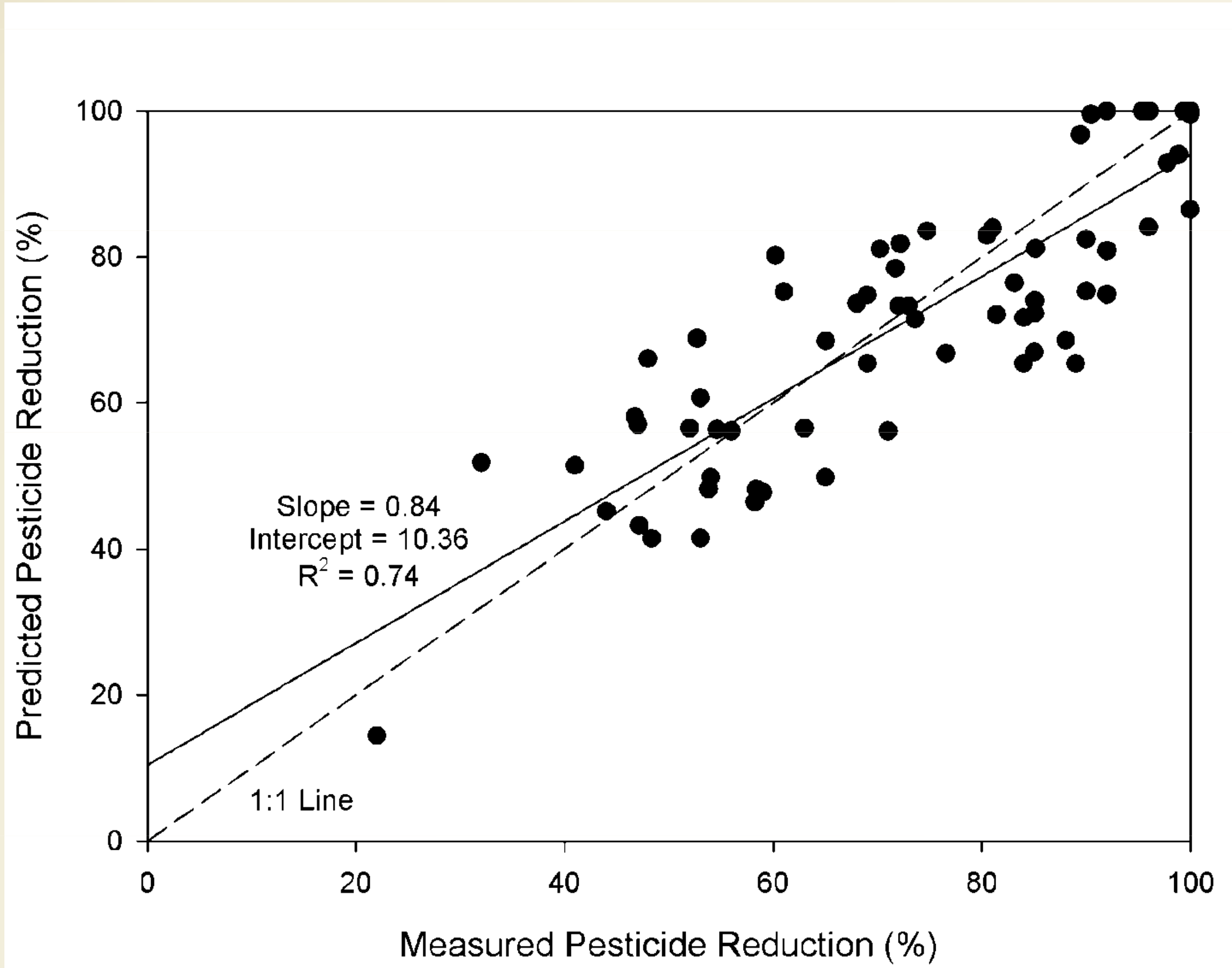
VFSMOD – Δ*Q* and Δ*E*

- VFSMOD able to predict runoff and sediment reduction



VFSMOD/Empirical Equation – ΔP

- Combined VFSMOD/empirical equation able to predict VFS performance

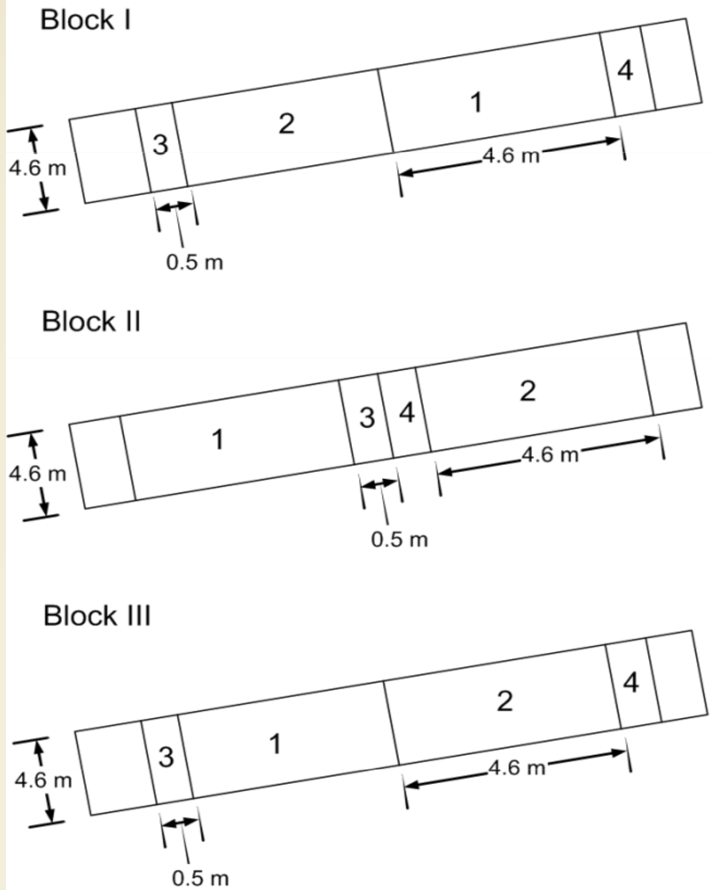


Potential Questions

- What about the effect of flow uniformity?
  - Can the procedure account for concentrated flow?
- Are the empirical regression parameters transferable?
  - Evaluation with additional data sets

Chlorpyrifos/Atrazine Study

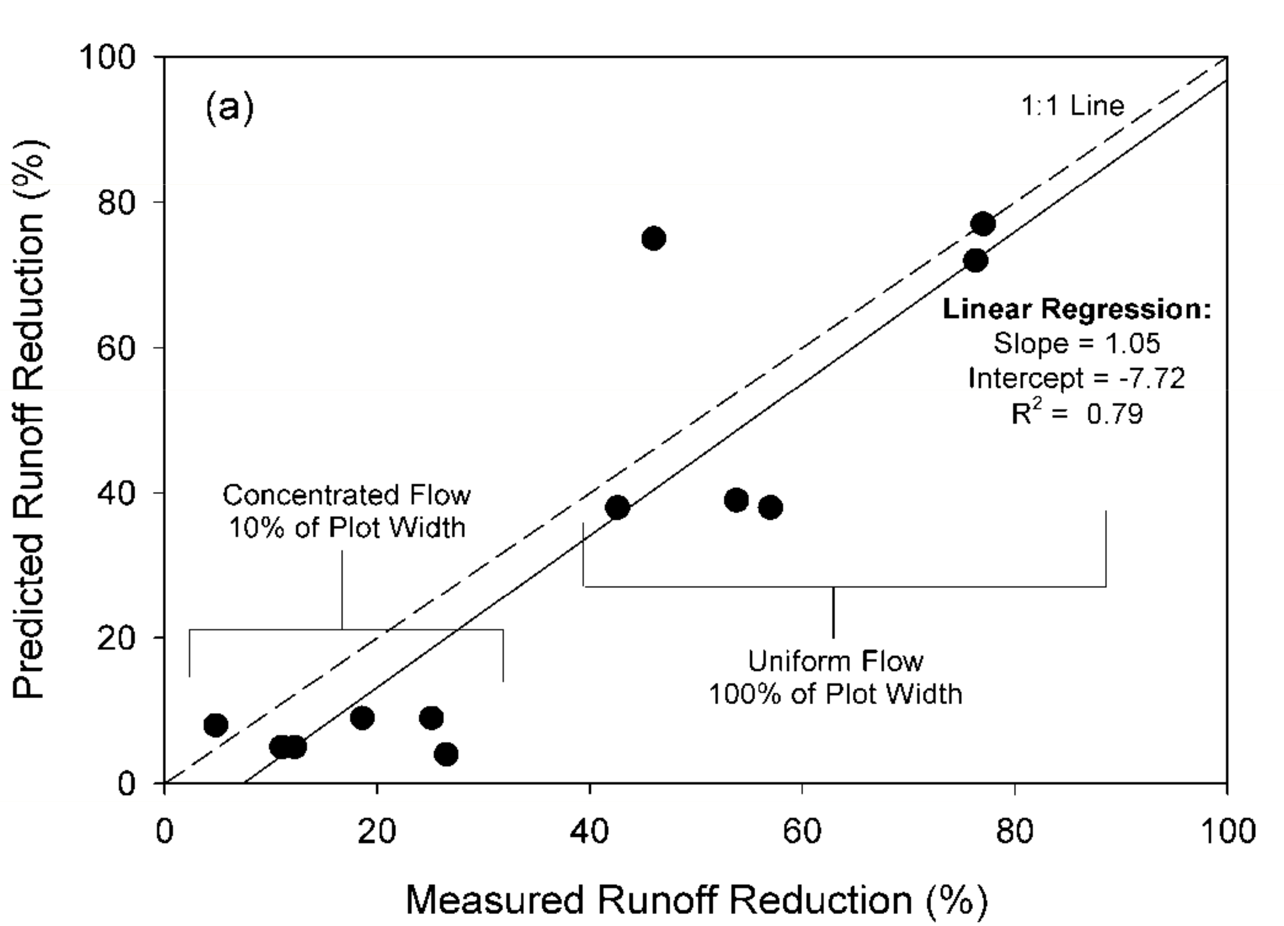
- Two Factors:
  - Flow Volume
  - Sheet vs. Concentrated Flow



Treatment Number	
1	100% Plot Width, 15:1
2	100% Plot Width, 30:1
3	10% Plot Width, 15:1
4	10% Plot Width, 30:1

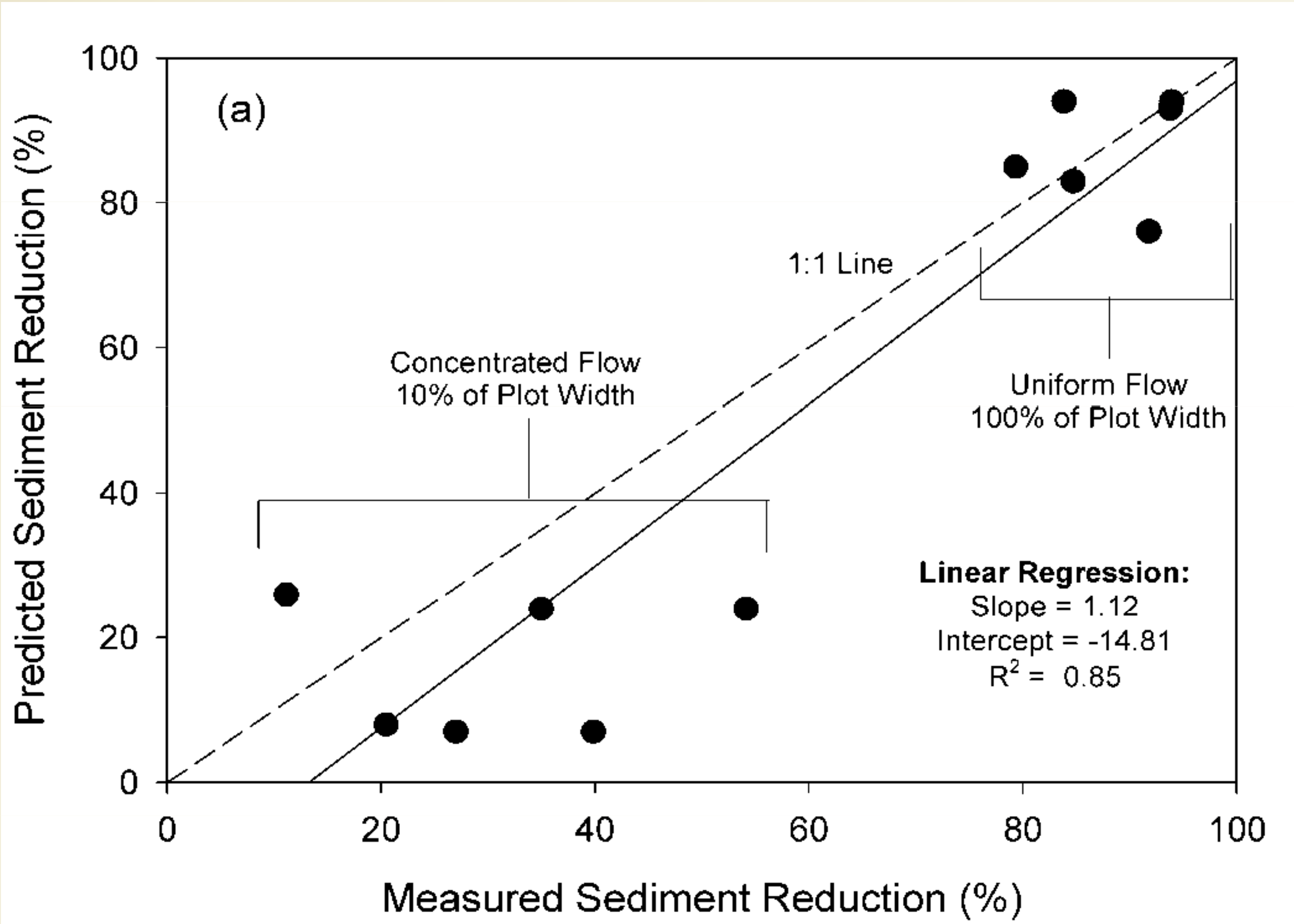
Chlorpyrifos/Atrazine Study

- VFSMOD able to predict uniform and concentrated flow runoff



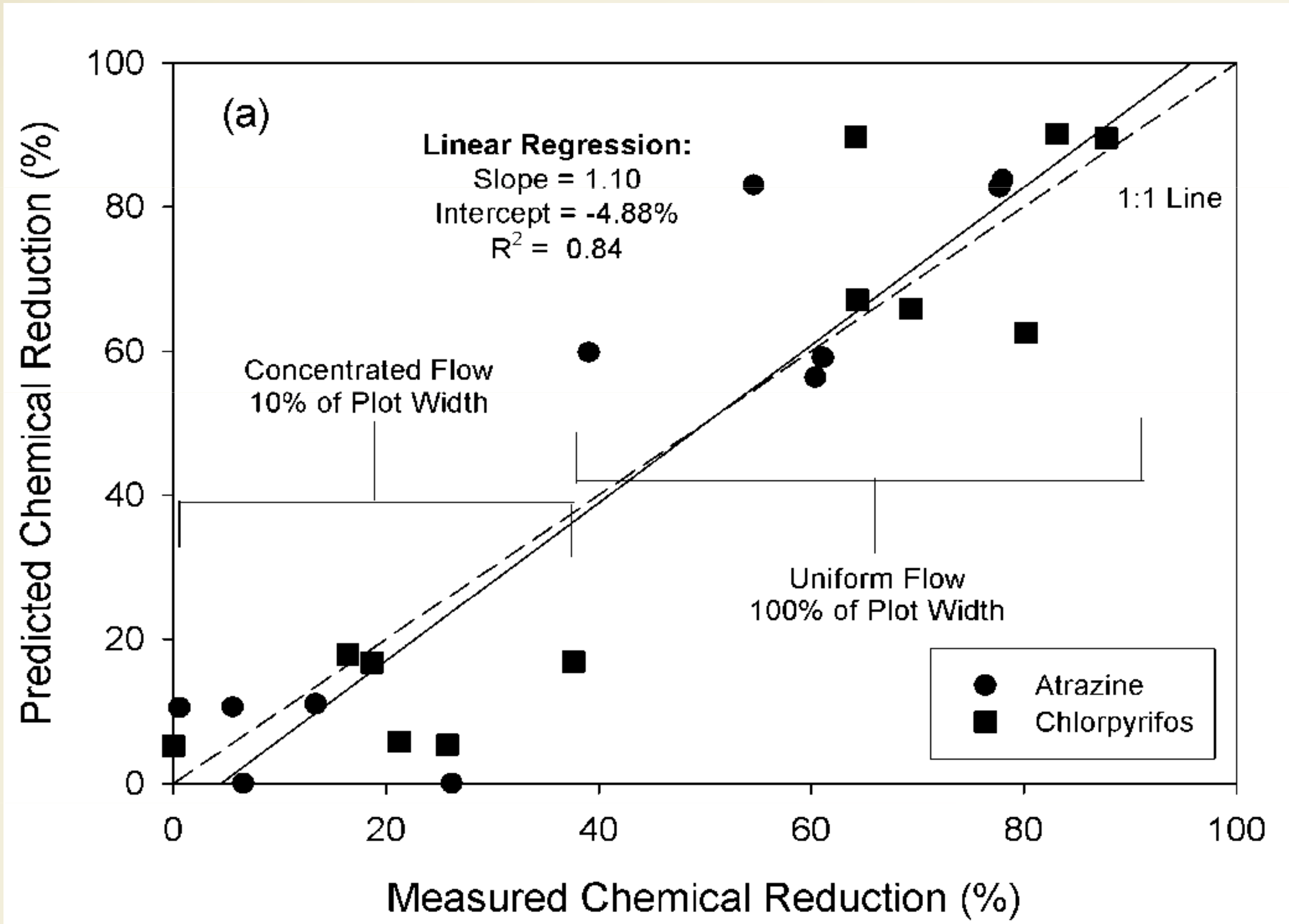
Chlorpyrifos/Atrazine Study

- VFSMOD able to predict sediment reduction



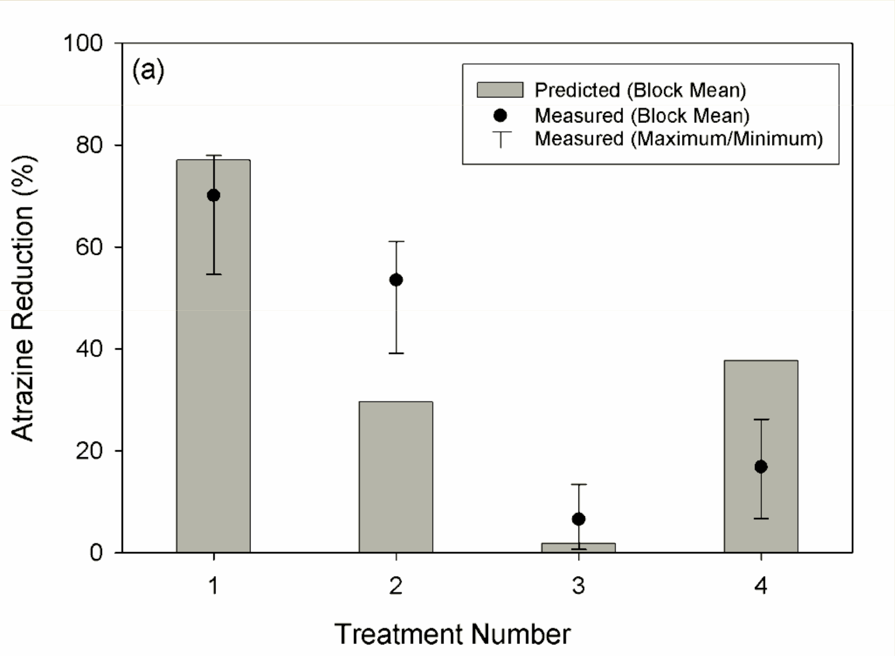
Chlorpyrifos/Atrazine Study

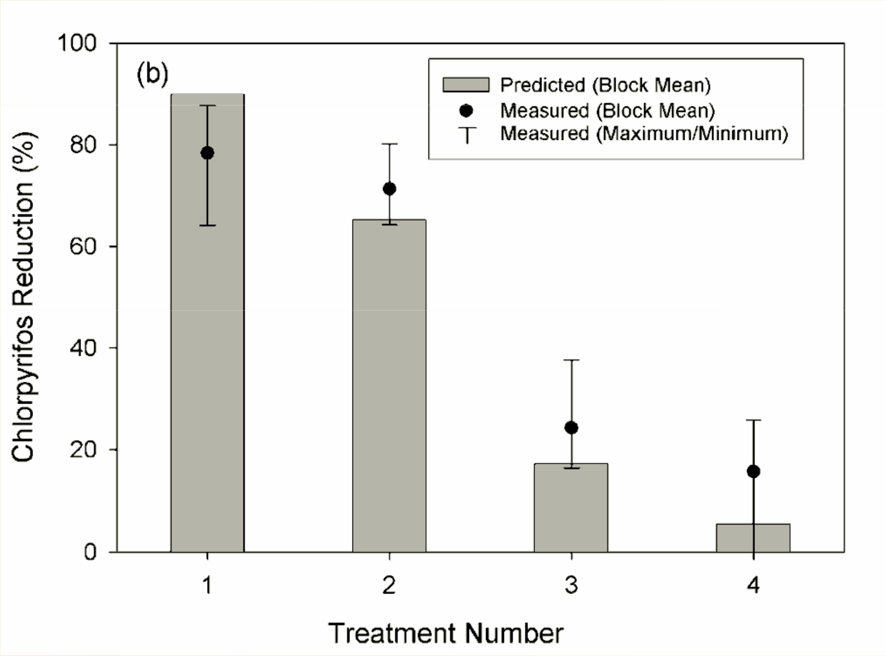
- Combined VFSMOD/empirical equation able to predict VFS performance



Chlorpyrifos/Atrazine Study

- Treatment effects for pesticide reduction (%):





Conclusions

- Key Drivers: Hydrologic response
- Physical VFS characteristics and pesticide reduction correlations insufficient to predict buffer efficiency in practice
- Combined mechanistic model (VFSMOD) with empirical trapping efficiency equation
  - Appropriate for both uniform and concentrated flow

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Questions?