BMP Effectiveness Evaluation in a CEAP Watershed: What Did We Learn from Watershed Modeling?

Indrajeet Chaubey, Lichi Chiang
Purdue University

Margaret Gitau
Florida A&M University

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Purdue University
Agricultural and Biological Engineering
University of Arkansas
Division of Agriculture

Modeling team

- Model setup and execution
  - Indrajeet Chaubey, Margaret Gitau, Lichi Chiang, Chetan Maringanti, Sayeed Mohammed
- Input data and review of results
  - J. Pennington, J. Popp, E. Gbur, G. Rodriguez
- SWAT Team input
  - Jeff Arnold, Nancy Sammons, Mike White

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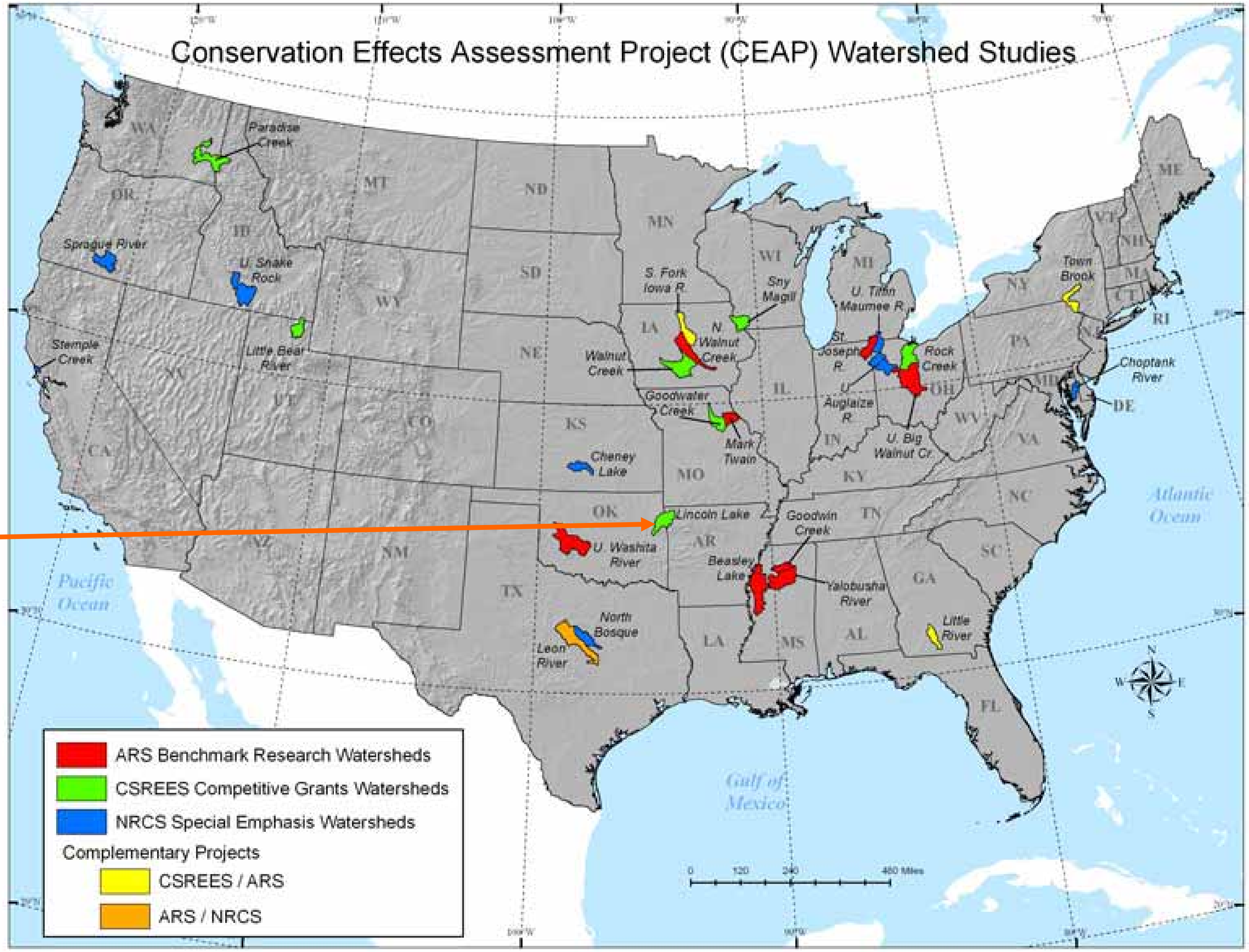
Study Location: Lincoln Lake Watershed

Lincoln Lake Watershed



Objective – Watershed modeling

- Quantify linkages among nutrient management, land use, BMP implementation, and water quality response at watershed level
  - Model water quality impacts of BMPs using SWAT model
  - Collect stakeholder feedback on modeling scenarios
- Outputs of interest: Soluble P, Total P, Nitrate N, Total N, Sediment, Biomass, and Yield

Modeling strategies for watershed response prediction

- Hindcast:
  - How much improvements could have been achieved under various watershed management conditions?
  - Compare with the monitoring data to evaluate if right management decisions were taken in the watershed
- Futurecast:
  - Given the current conditions, what can be done to improve the water quality in future?
  - This may help set realistic expectations
    - One of the recommendations by the CEAP Blue Ribbon Panel

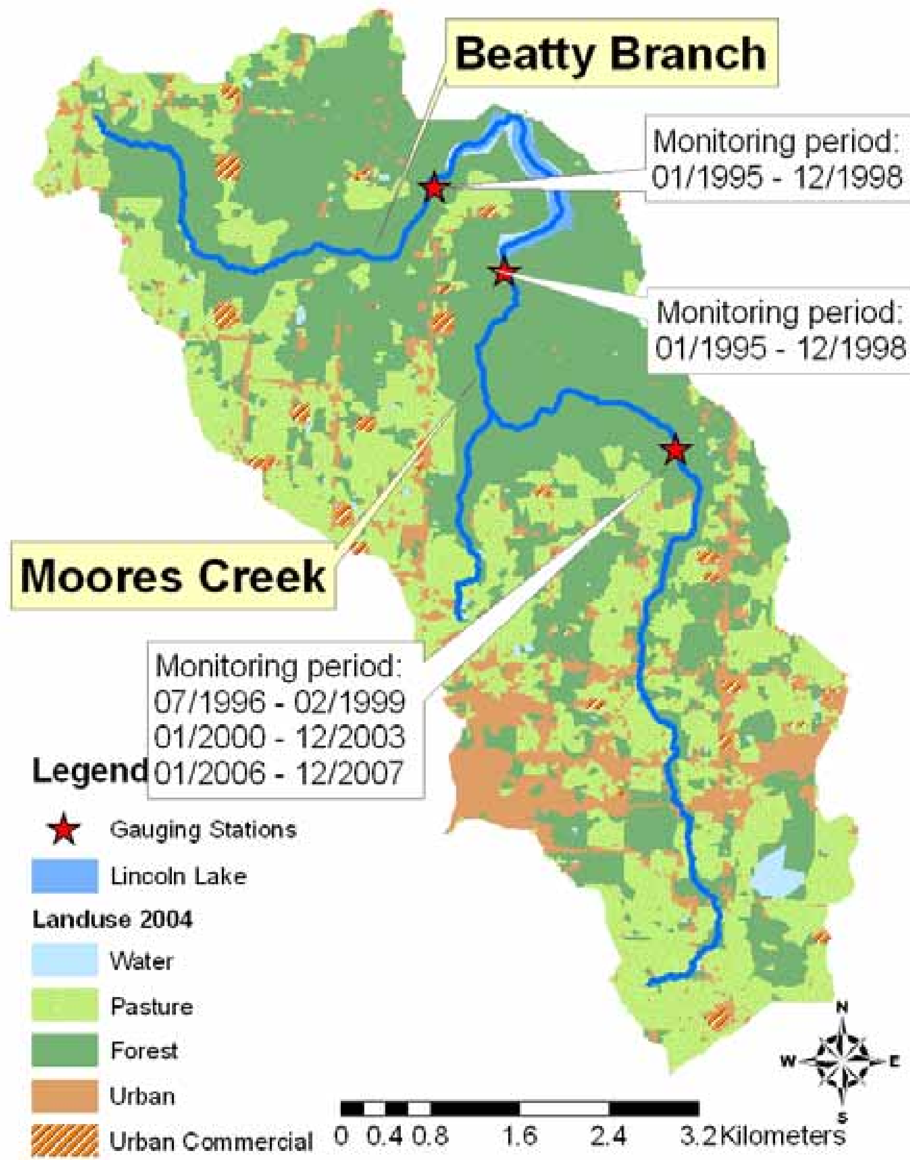
Key modeling questions

- How do various combinations of BMPs improve water quality at various spatial and temporal scales?
- How does uncertainty in future weather and climate conditions affect BMP performance?
- In a dynamic watershed, how can we differentiate land use impacts from BMP impacts on water quality?
- What is the spatial domain of influence of BMPs in improving water quality?

Modeling challenges

Land use:
Pasture 36%
Forest 39%
Urban 12%

- Available data at various spatial and temporal resolution
- Watershed is very dynamic
- Various externalities have resulted in dynamics watershed management



BMP scenarios modeled in SWAT

3 BMP categories(total of 171 BMP scenario combinations) + 2004 baseline => 172 BMP scenarios

Nutrient management		
	poultry litter	alum-amended litter
	No application	
spring	1, 1.5, 2 ton/acre	
summer	1, 1.5, 2 ton/acre	
fall	2, 2.5, 3 ton/acre	

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grazing and pasture management
no grazing
optimum grazing
over grazing

3

Buffer width
0 m
15 m
30 m

3

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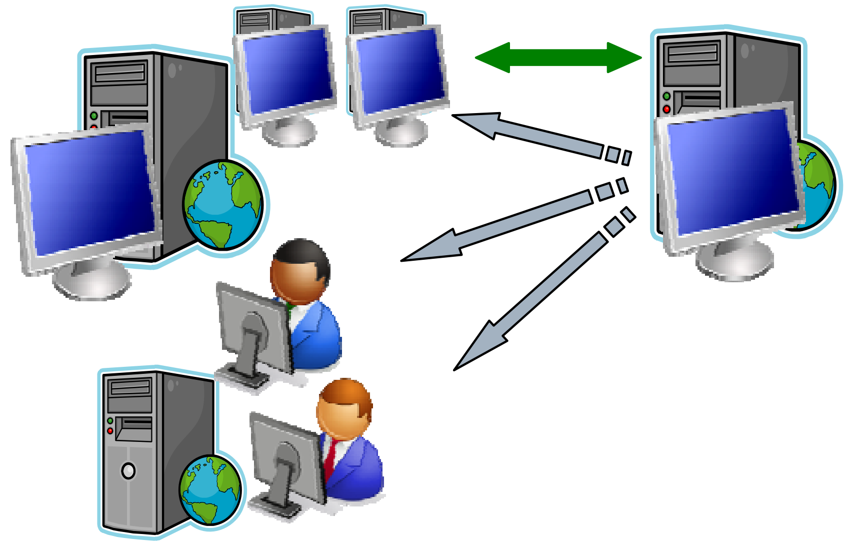
Weather data

- Period of interest – 2004 – 2028
  - Based on the expected life of BMP and minimum data needed for economic analyses
- Weather data generated using WXGEN program based on historical measured data in the watershed
- 250 weather realizations used in this study
- Weather data were same for all 172 BMP scenarios

Challenges

- Number of runs
  - 172 BMP scenarios, 250 weather realization data/BMP scenario = 43,000 SWAT runs
  - Time/run = 8-10 mins (LINUX); 5,700 CPU hrs
- Space – temporary storage for output
  - Output files 1*59 Mb, 3*2.5 Mb per run
  - Total 67.5 Mb/run – minimum 2.5 Tb

Approaches - *Condor*



- Modified, configured SWAT to run on TeraGrid Condor network and produce minimum required output for each run

- Prepared input files for batch runs – weather, management, options

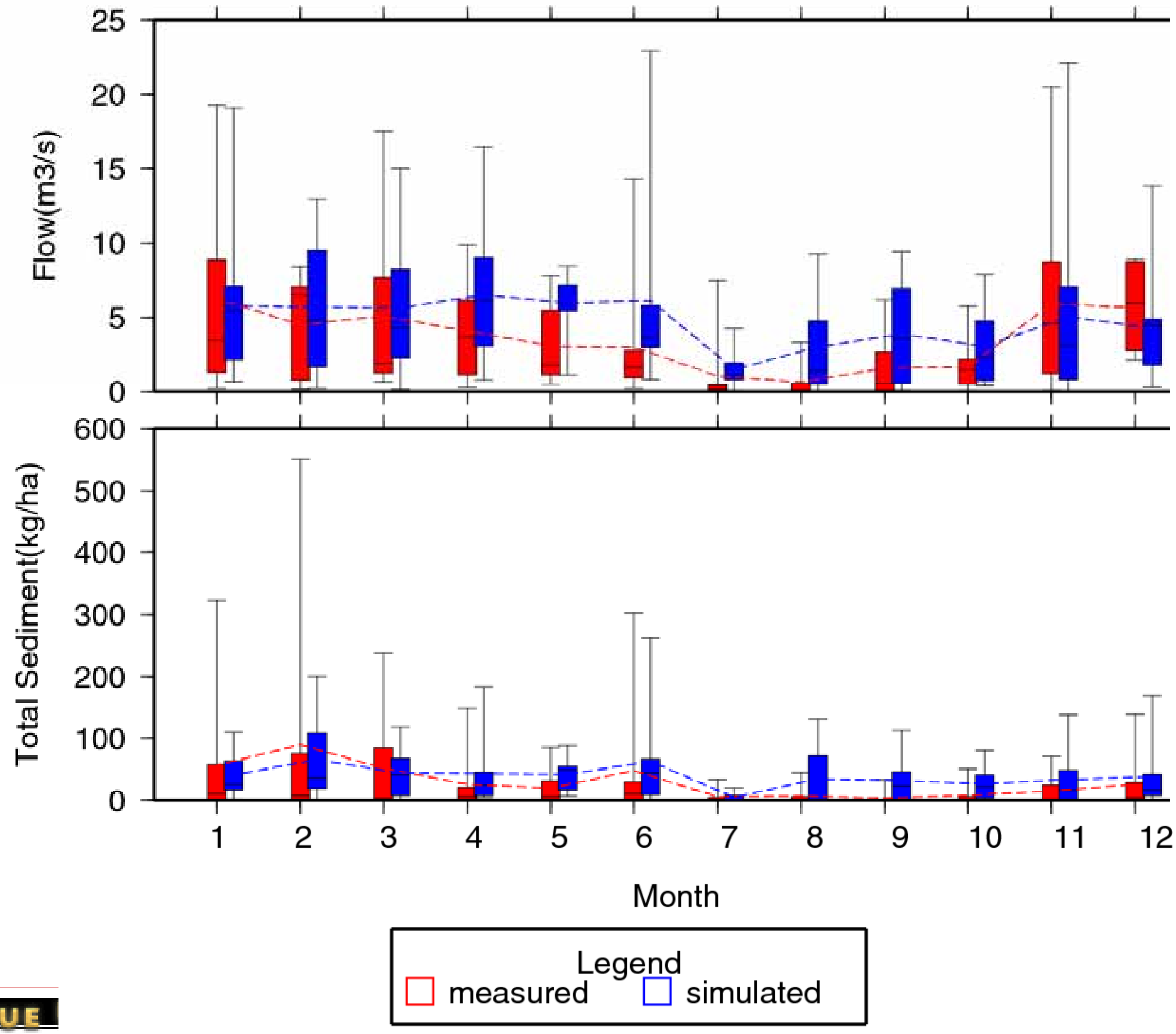
- Developed scripts and post-processing tools to handle model runs and outputs.

Baseline model results: flow and sediment

❑2004 model as the baseline model

❑Detailed measured watershed data used to develop the model

❑Model is calibrated minimally as not to change the parameter values drastically from the baseline



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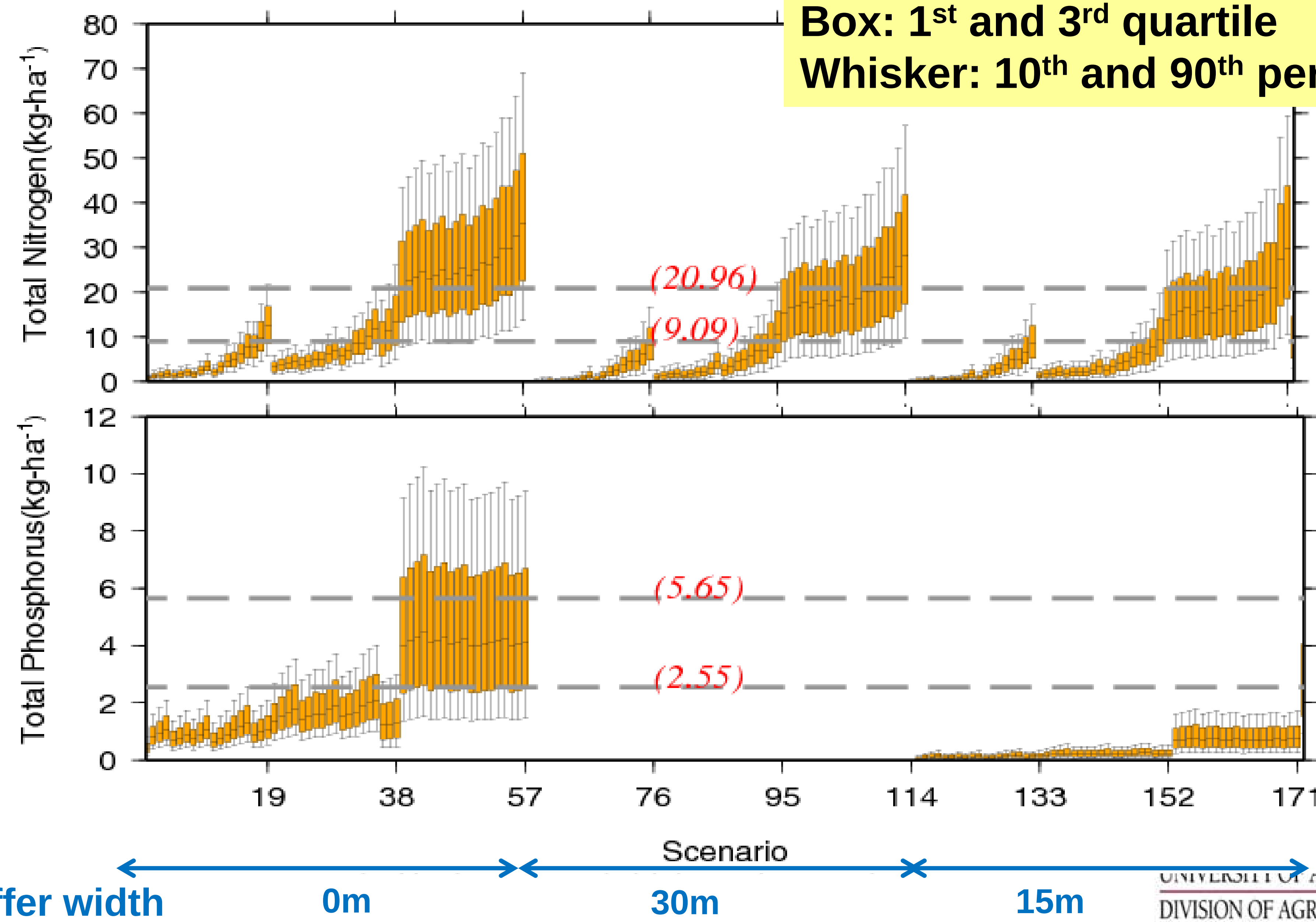
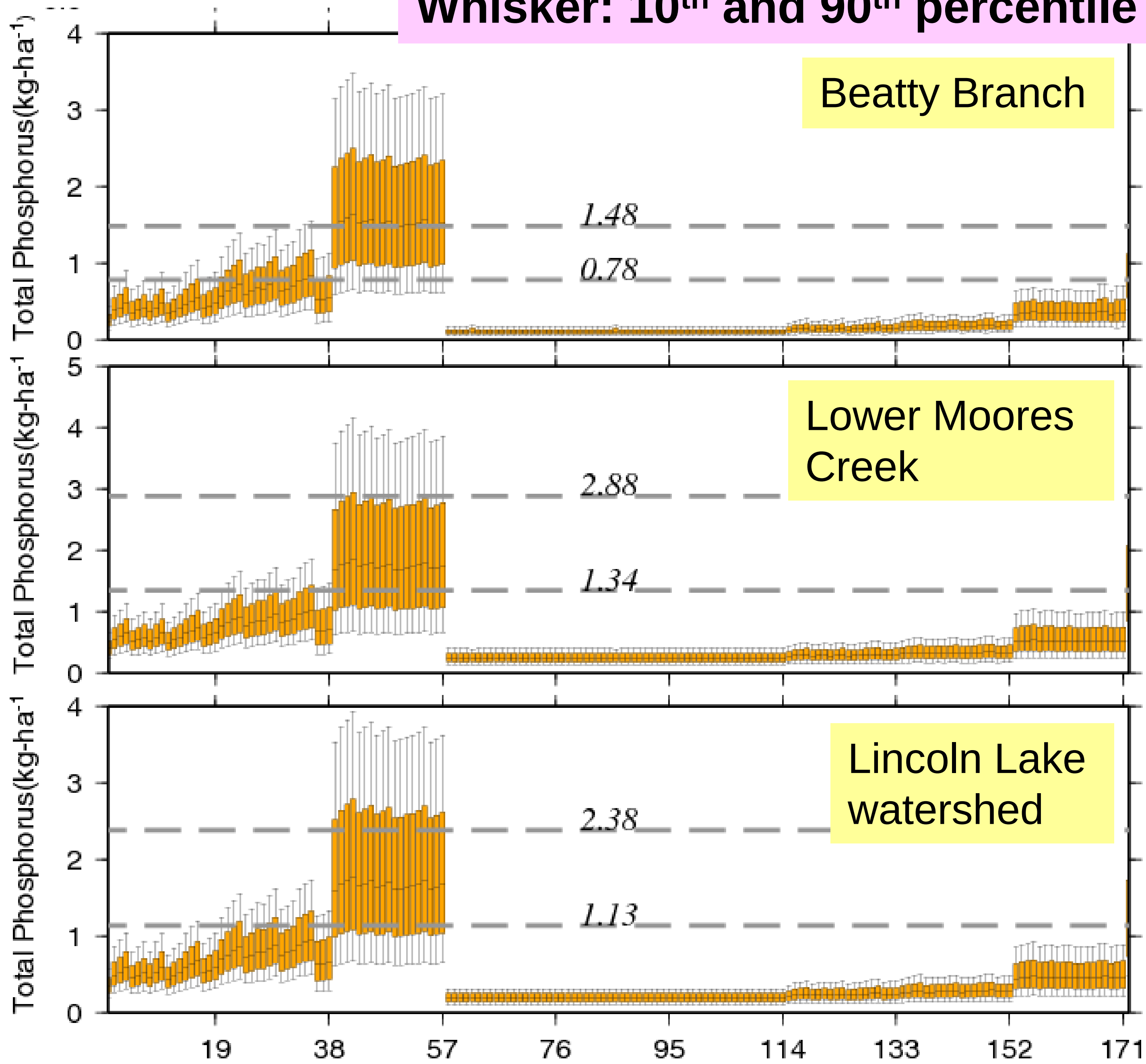
Annual N and P losses from pastures

Box: 1st and 3rd quartile
Whisker: 10th and 90th percentile



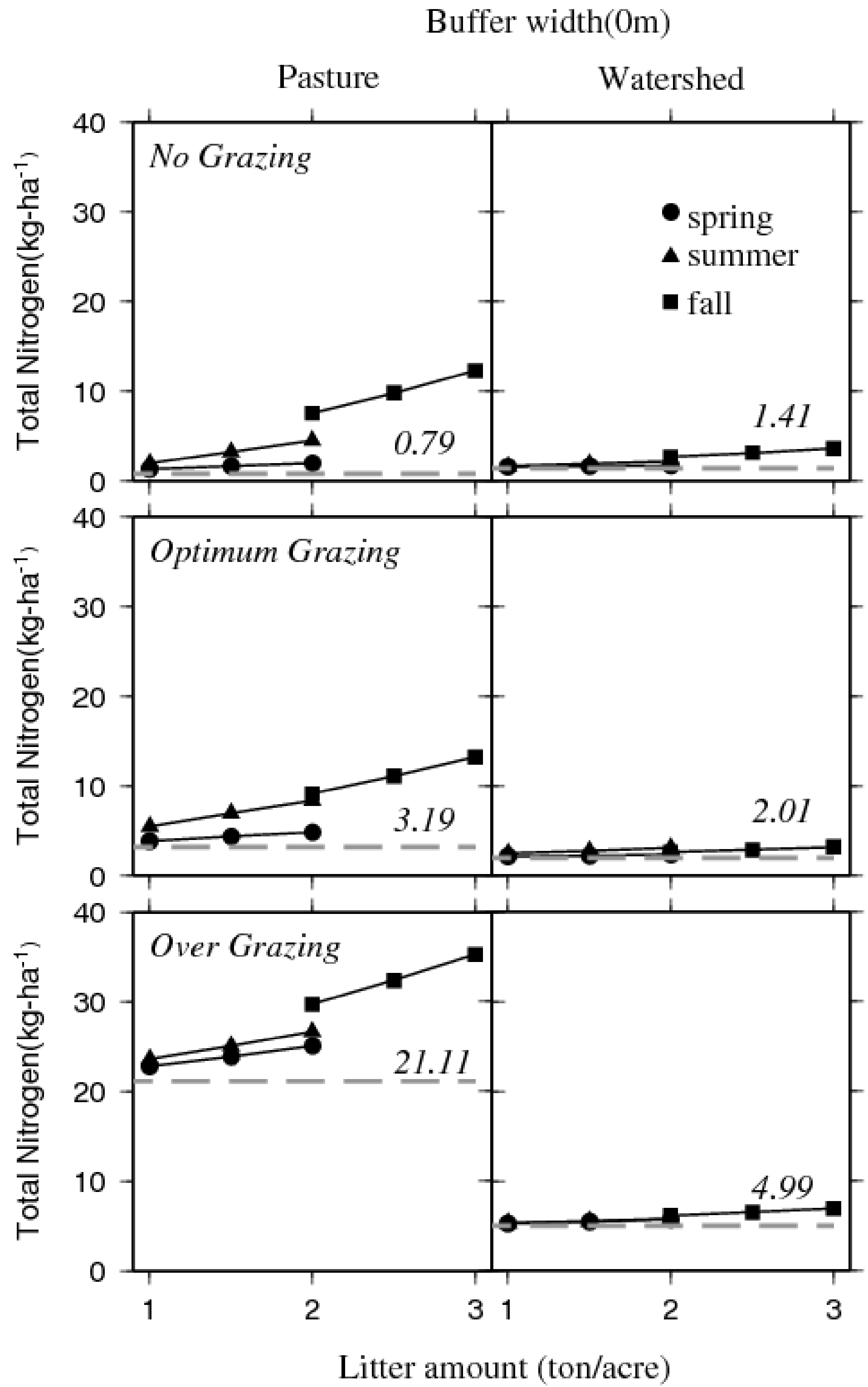
Annual TP(kg/ha) at sub-watersheds and whole watershed

Box: 1st and 3rd quartile
Whisker: 10th and 90th percentile



Comparison of TN losses from pasture land and whole watershed

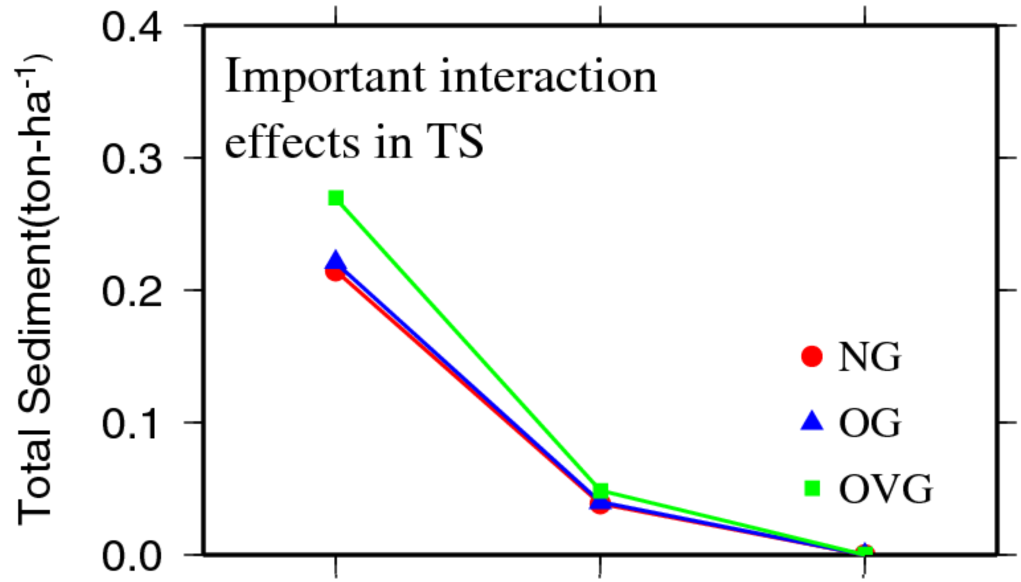
- Dash line is with no litter application
- Fall litter application can result in the greatest TN loss, except with optimum grazing.
- Overall, TN loss increases with the intensity of grazing.

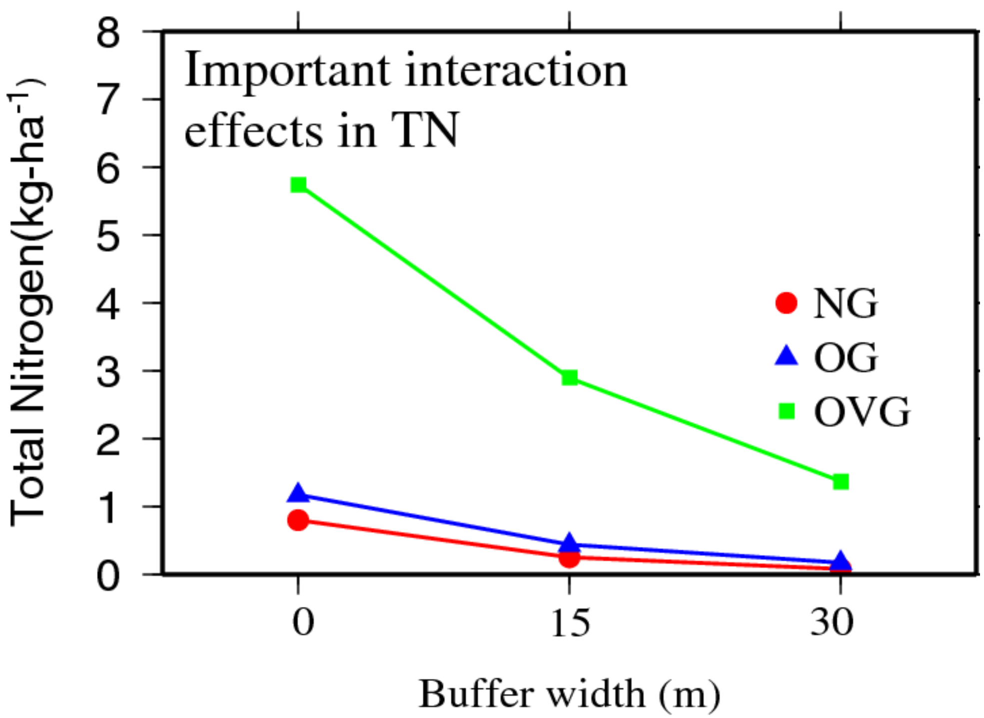


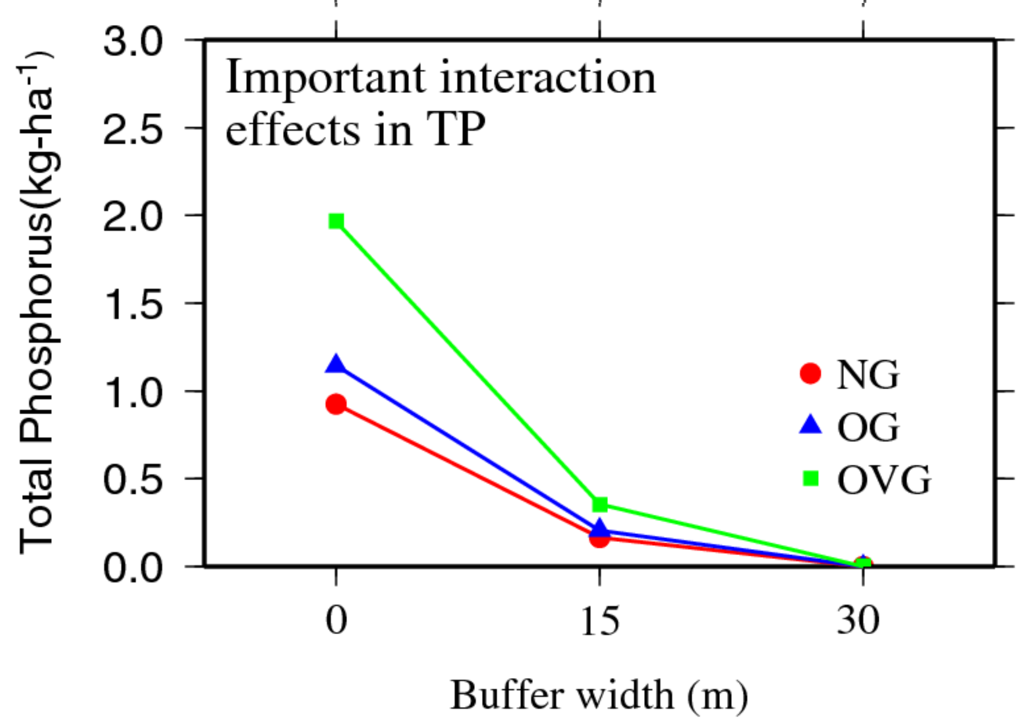
Interaction effects of BMPs: Grazing and Buffer management

Grazing management
NG: no grazing
OG: optimum grazing
OVG: over grazing

Buffer width
0 m
15 m
30 m



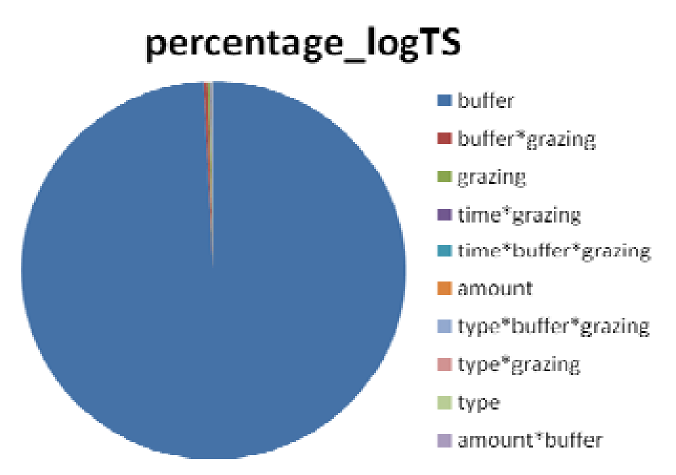


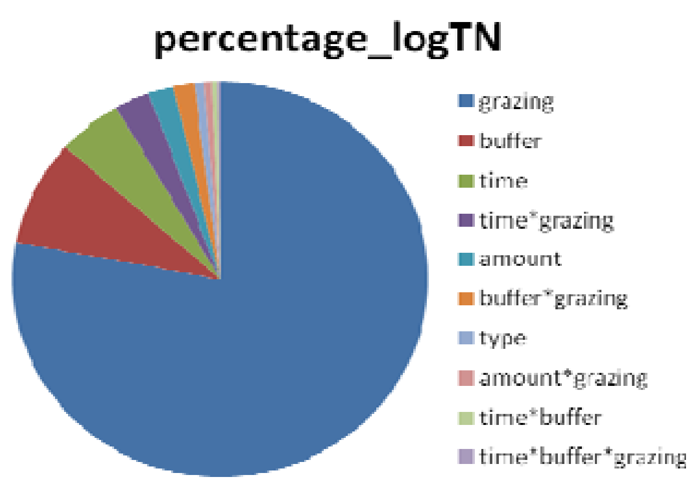


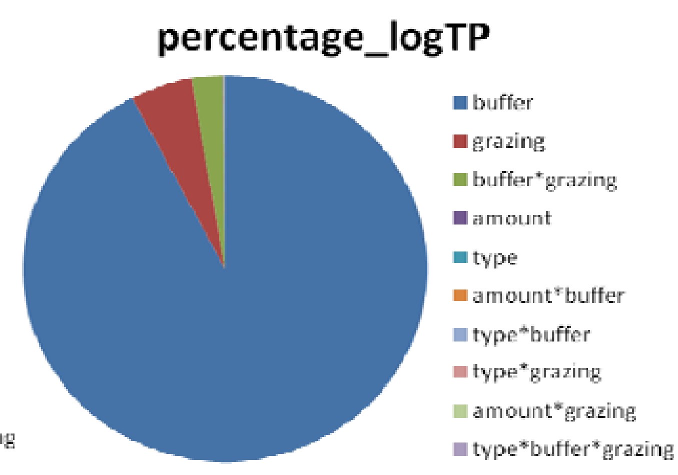
ANOVA results

P<.0001	logTS	logTN	logSolP	logTP
R-square	0.83	0.77	0.93	0.94

Rank	source (logts)	%	source (logtn)	%	source (logtp)	%
1	buffer	99.10	grazing	77.35	buffer	92.33
2	buffer*grazing	0.30	buffer	8.61	grazing	4.94
3	grazing	0.19	time	5.00	buffer*grazing	2.52
4	time*grazing	0.08	time*grazing	2.71	amount	0.05
5	time*buffer*grazing	0.05	amount	1.98	type	0.04
6	amount	0.04	buffer*grazing	1.60	amount*buffer	0.02
7	type*buffer*grazing	0.03	type	0.77	type*buffer	0.02
8	type*grazing	0.02	amount*grazing	0.58	type*grazing	0.02
9	type	0.02	time*buffer	0.41	amount*grazing	0.01
10	amount*buffer	0.02	time*buffer*grazing	0.24	type*buffer*grazing	0.01







Buffer simulation in SWAT

The filter strip trapping efficiency for sediment, nutrients and pesticides

$$trap_{ef,sed} = 0.367 * (FILTERW)^{0.2967}$$

FILTERW is the width of the filter strip.
Trap is the fraction of bacteria, sediment, pollutant loading trapped by the filter strip.

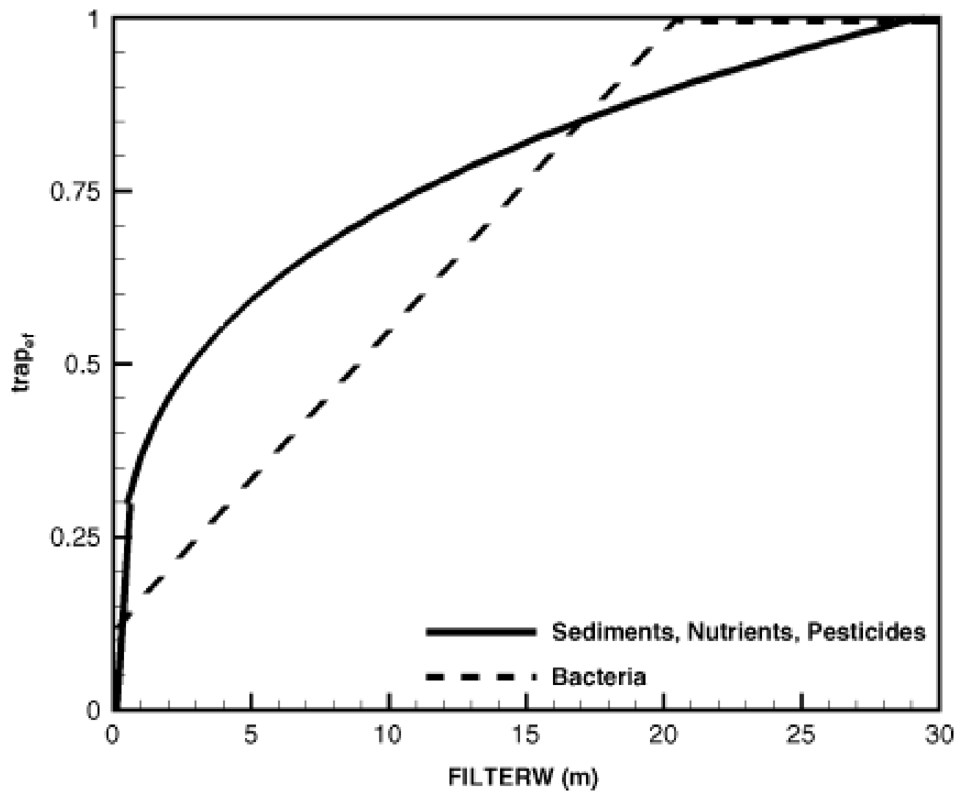
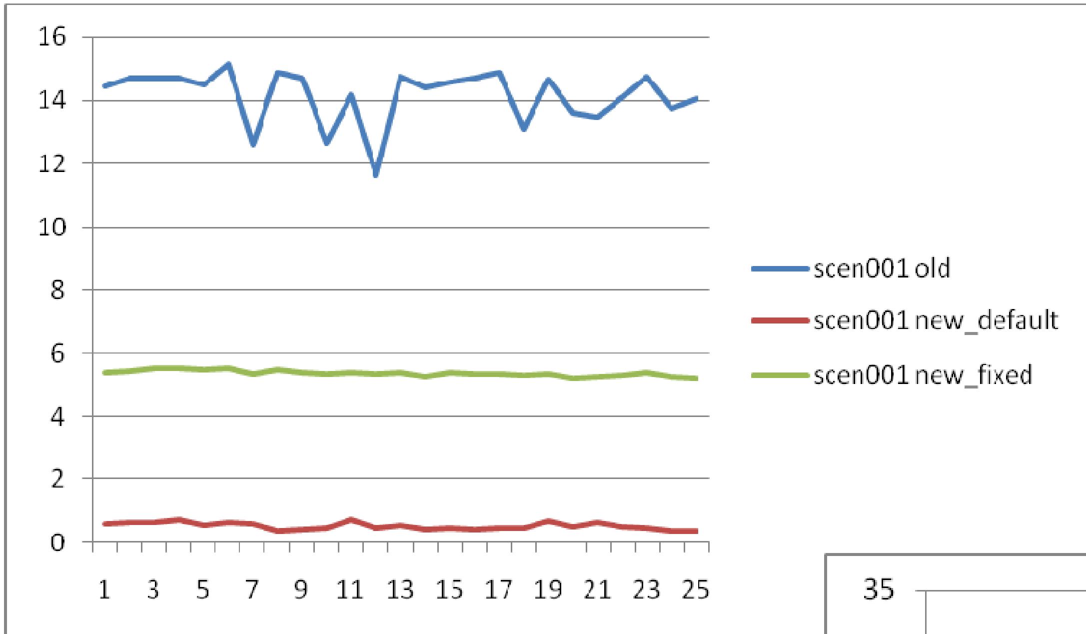
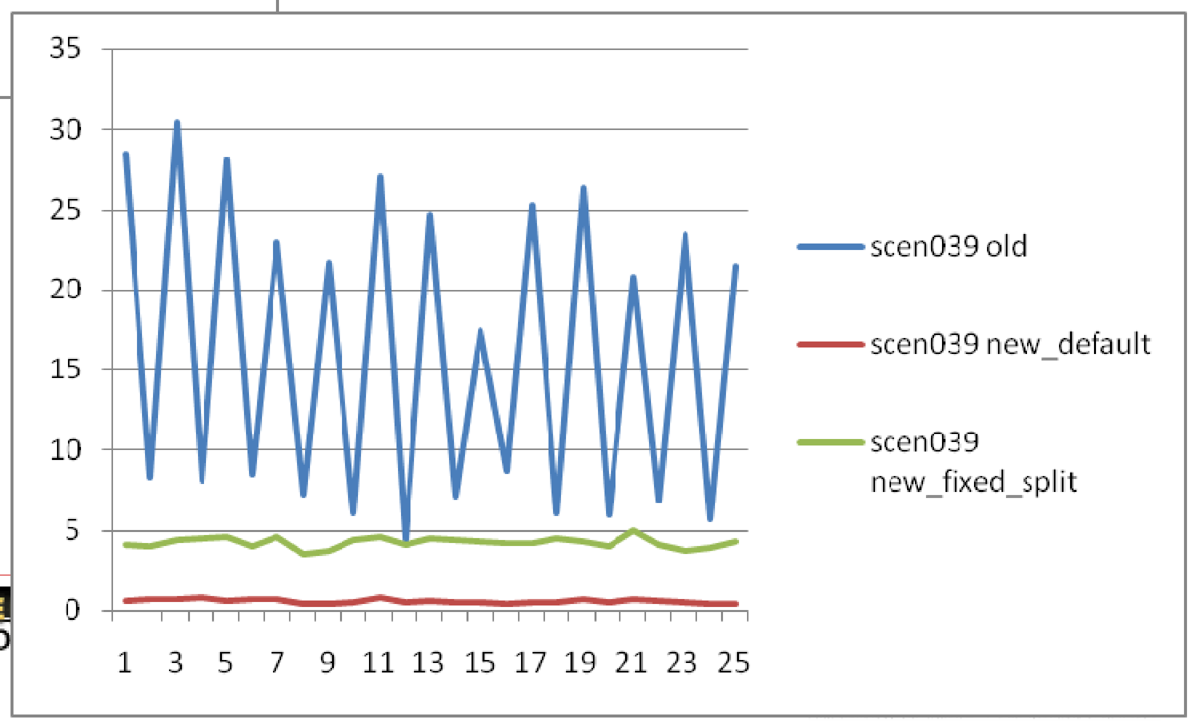


Figure. Effect of strip width on trapping efficiency of vegetative strips (Figure from Mazdak et al., 2007)

Additional challenges: biomass and yield



Extremely low biomass values with new_default



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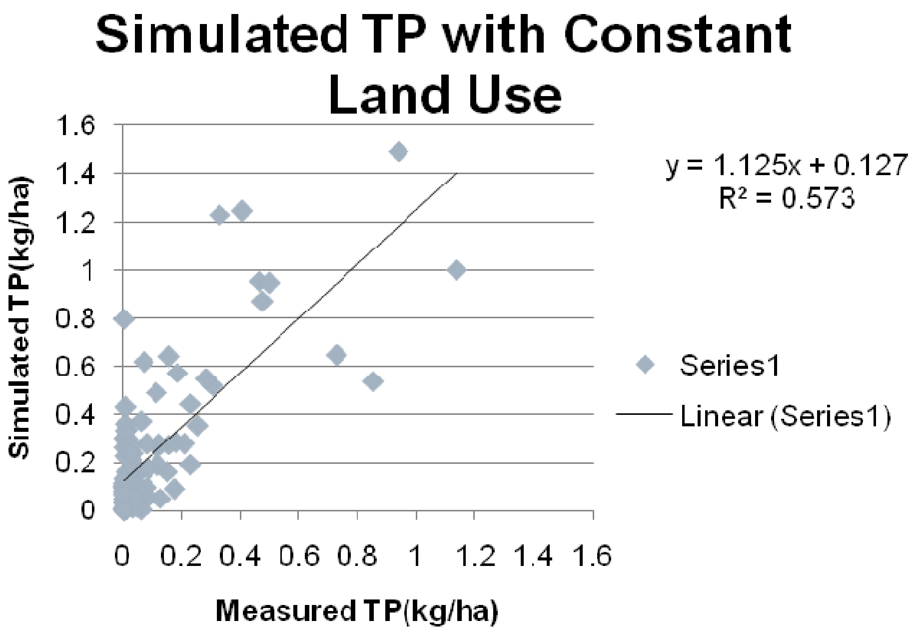
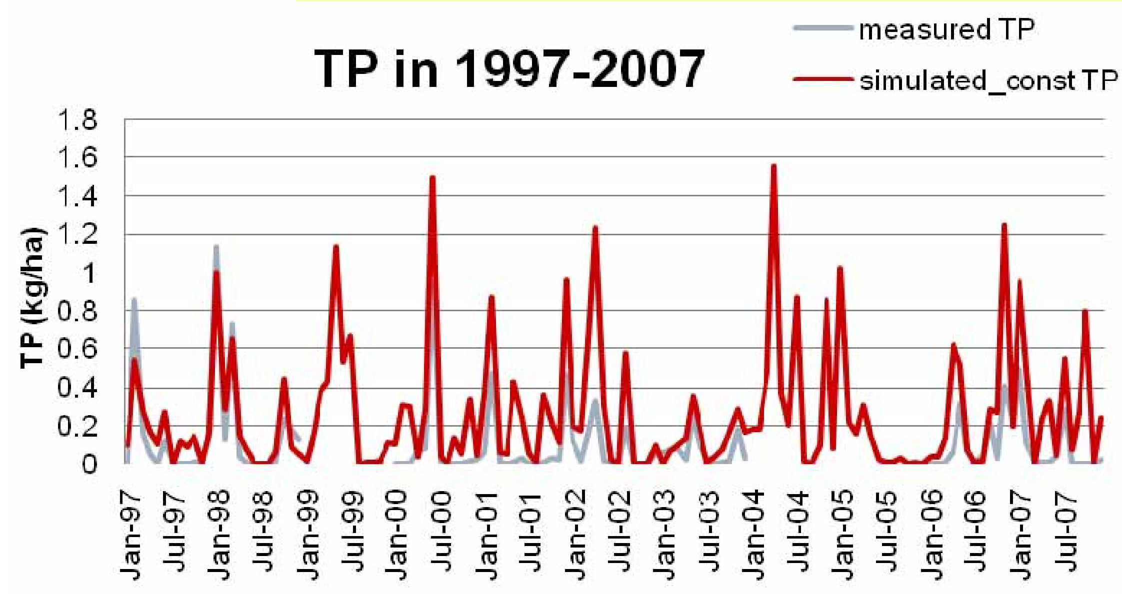
How can we differentiate land use change effects from BMP effects?

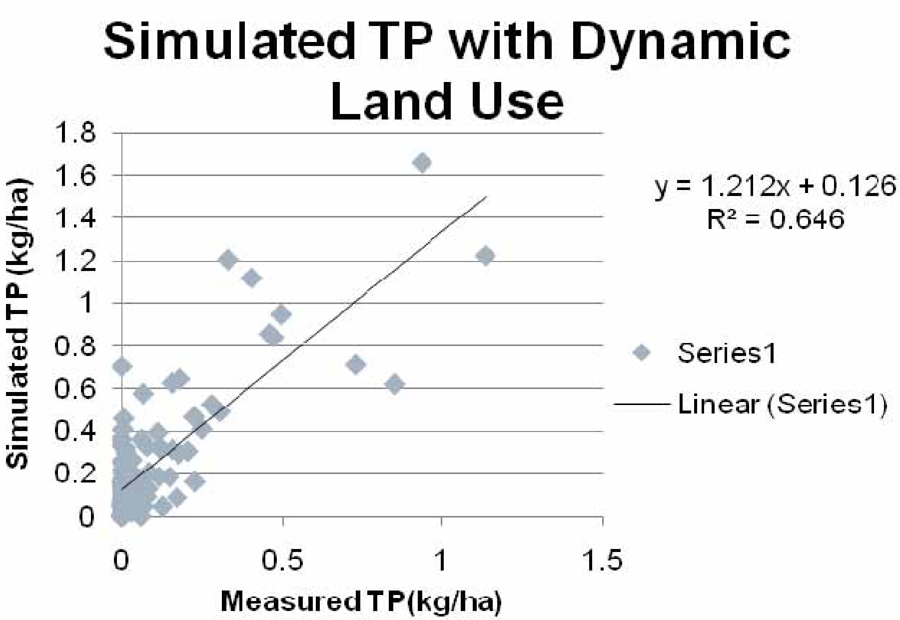
- Hypothesis: In agricultural watersheds, land use changes can mask the water quality improvements from the BMPs implemented in the watershed
- SWAT Code modified to change land use dynamically with time

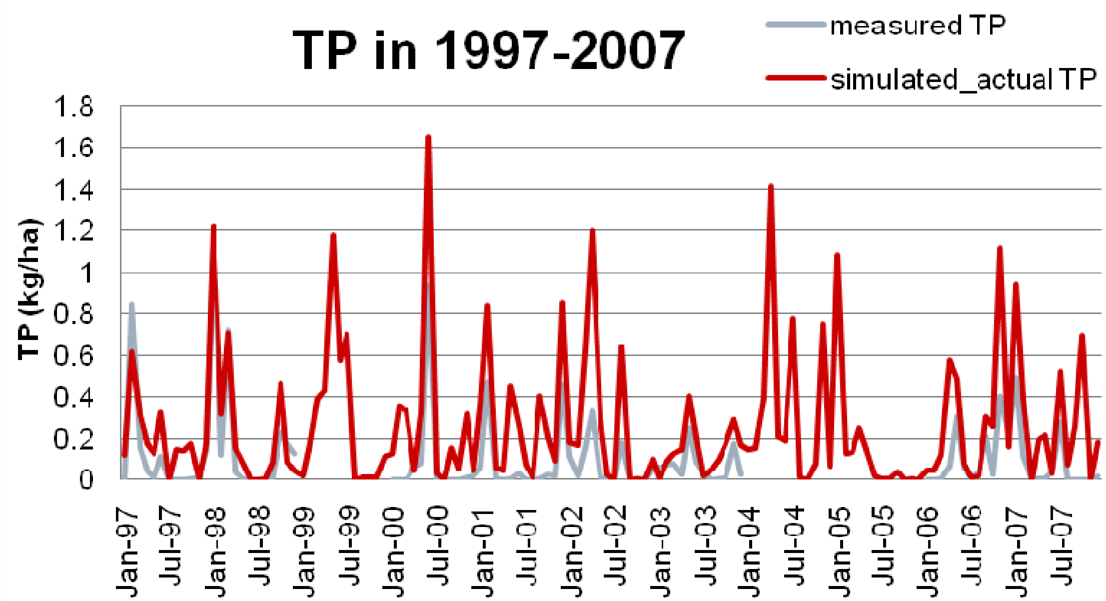
Preliminary results

Measured: at Upper Moores Creek
Simulated_constant: with 2004 land use data
Simulated_actual: with 92-04 HRU fraction changes data









Lessons learned

- Greater amounts of sediment/nutrient losses coming from Upper Moores creek due to intensive pasture and urban land use.
- Grazing management followed by timing of litter application are important non-structural BMPs for reducing nutrient losses from pasture.
- Buffer strip is the most important structural BMP for reducing nutrient and sediment losses from pasture.
- Weather variability can result in significant uncertainty in BMP performance
- Simulation of buffer strip performance in SWAT needs to be modified.

Thank you

- ichaubey@purdue.edu

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