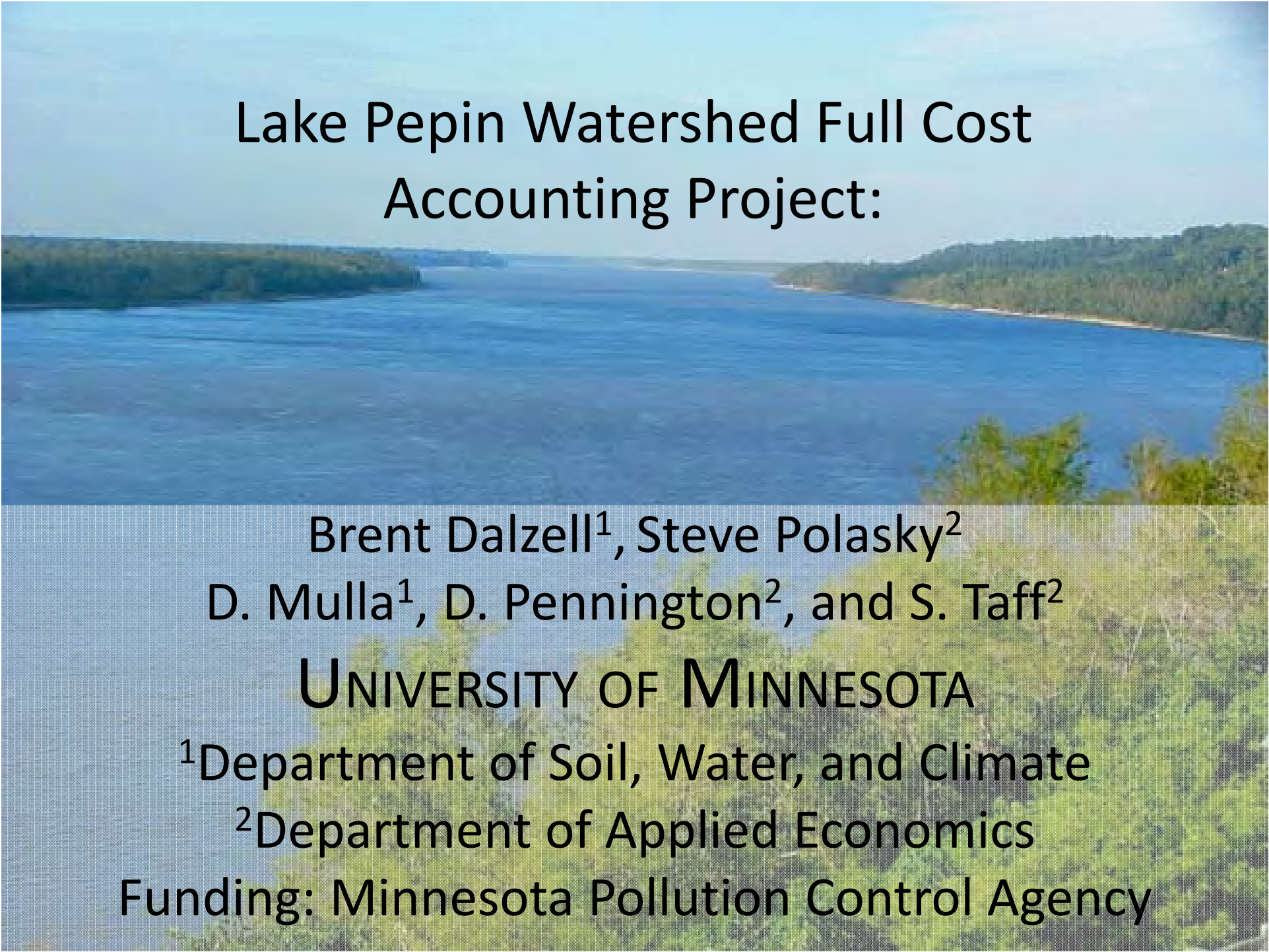




Lake Pepin Watershed Full Cost Accounting Project:

Optimum Landscape Allocation of Conservation Practices for Water Quality and Ecosystem Service Valuation.



Lake Pepin Watershed Full Cost Accounting Project:

Brent Dalzell¹, Steve Polasky²

D. Mulla¹, D. Pennington², and S. Taff²

UNIVERSITY OF MINNESOTA

¹Department of Soil, Water, and Climate

²Department of Applied Economics

Funding: Minnesota Pollution Control Agency

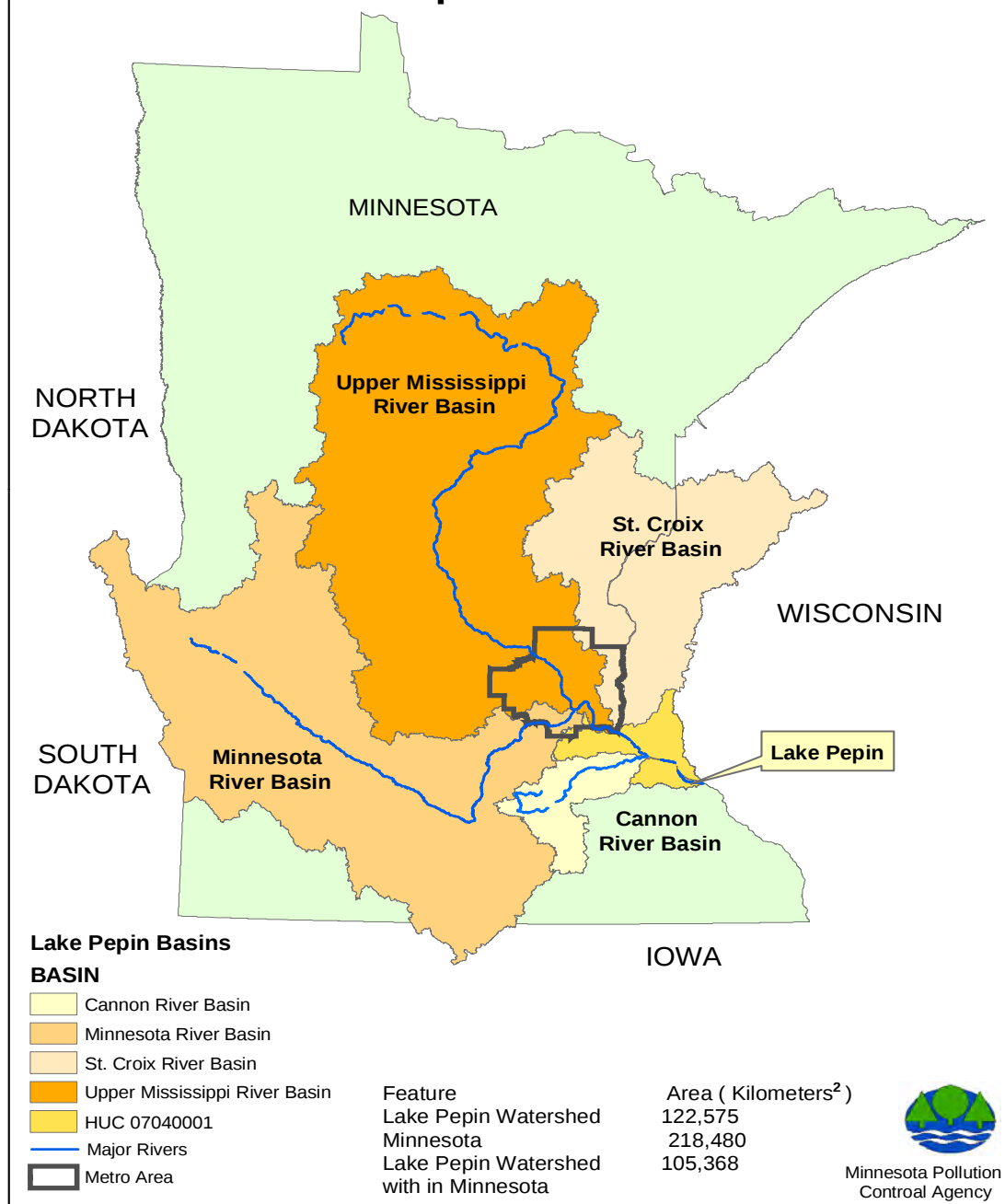


Lake Pepin (birth place of waterskiing – 1922)

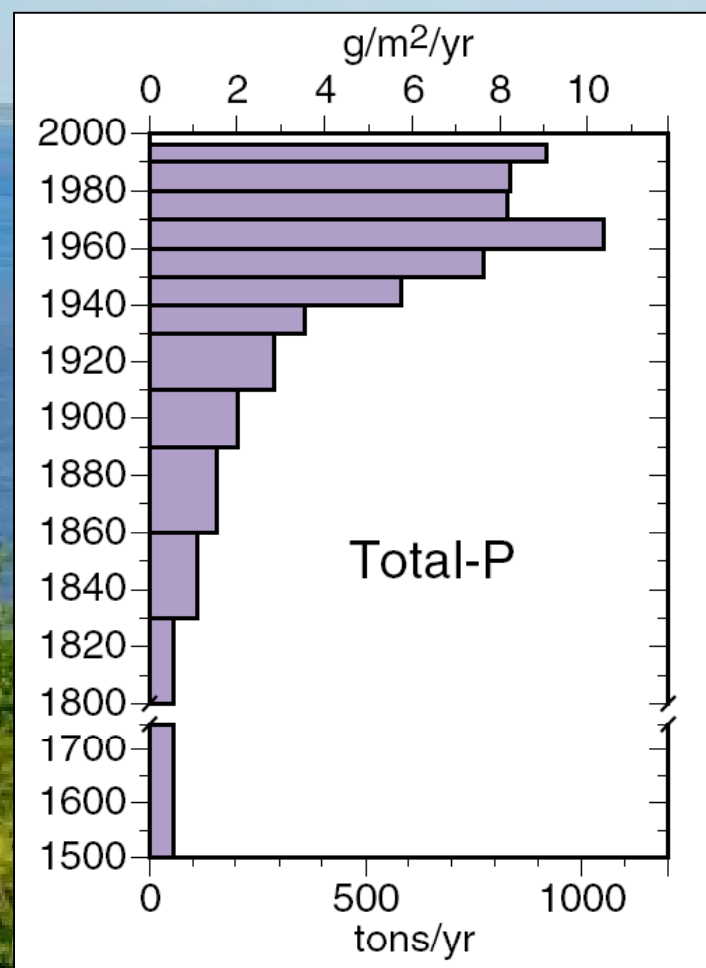
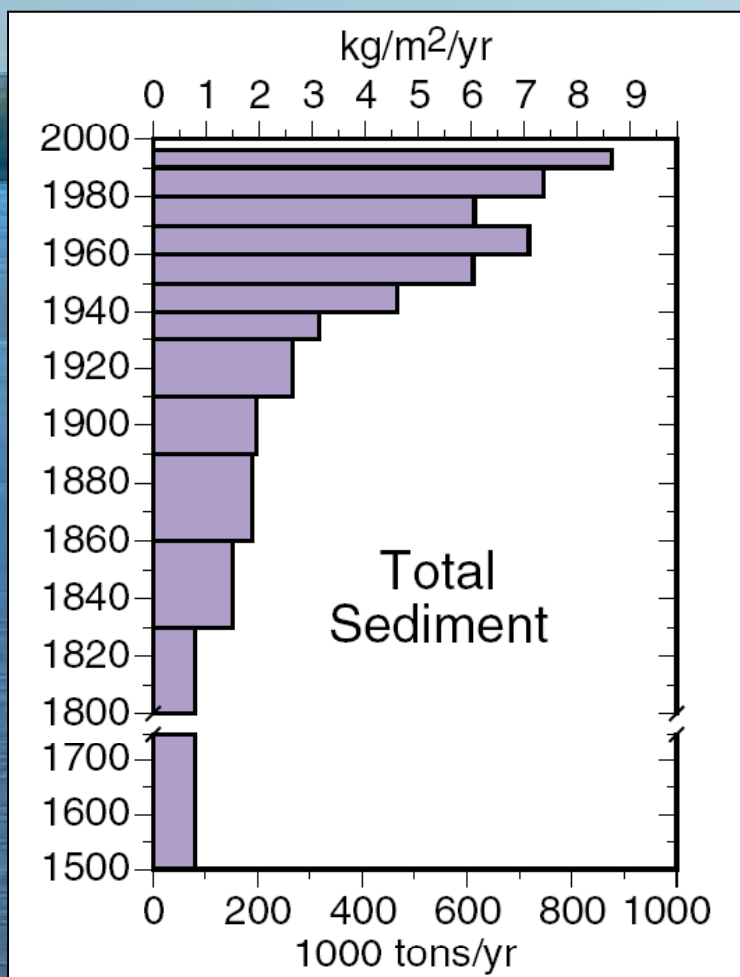
Minnesotans Love Their Water Resources



Lake Pepin Watershed



Sediment and phosphorus loading to Lake Pepin is occurring at an accelerated rate



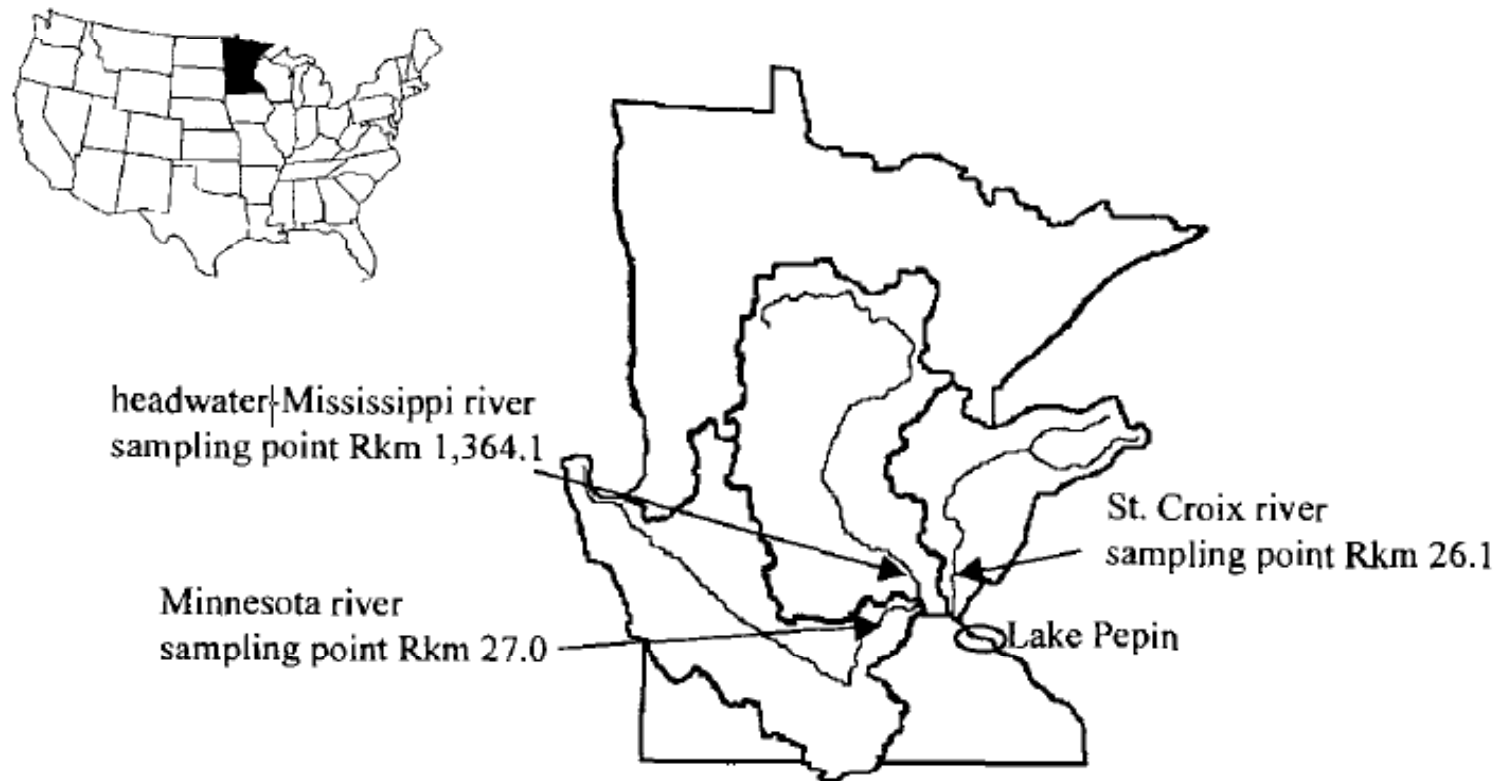


introduction

Lake Pepin TMDL: *Kelley and Nater, 2000.*

What's the problem?

J. ENVIRON. QUAL., VOL. 29, MARCH-APRIL 2000



- Minnesota River has always been a disproportionate source of sediment to Lake Pepin but its role has increased:
- 87 to 90% of the current sediment load originates in the MN River Basin.

TMDL Goal

- The Lake Pepin TMDL is expected to require from 25 to 50% reductions of P and sediment from current levels
- MPCA is obligated (Minn. Stats. 114D.25) to expand the scope of its TMDL analyses:
 - Examine the impacts of meeting TMDL goals on the area's water quality, carbon budget, habitat, and agricultural production
 - Estimate economic benefits and costs associated with attainment of water quality standards resulting from changes in management in the Lake Pepin watershed

How To Meet TMDL Goals?

- There are many potential changes in land use and land management that could meet TMDL goals
- We are assessing alternative land use/management scenarios to achieve water quality improvements
- Developing a comprehensive assessment of the net economic benefits associated with alternative scenarios for achieving TMDL goals

Marine & Terrestrial Ecosystem Services

- ***Ecosystem services*** are the contributions of nature to the provision of goods and services that contribute to human well-being
 - Provisioning (food, fuel, fiber...)
 - Regulating (carbon sequestration, water quality...)
 - Cultural (aesthetics, recreation...)



Marine & Terrestrial Ecosystem Services

natural
capital
PROJECT

Recreation

Aquaculture

Fisheries

Coastal Protection

Wave Energy

Aesthetic Quality

Water Quality

Habitat Quality

Carbon Sequestration



Sediment retention

Water purification

Crop pollination

Hydropower

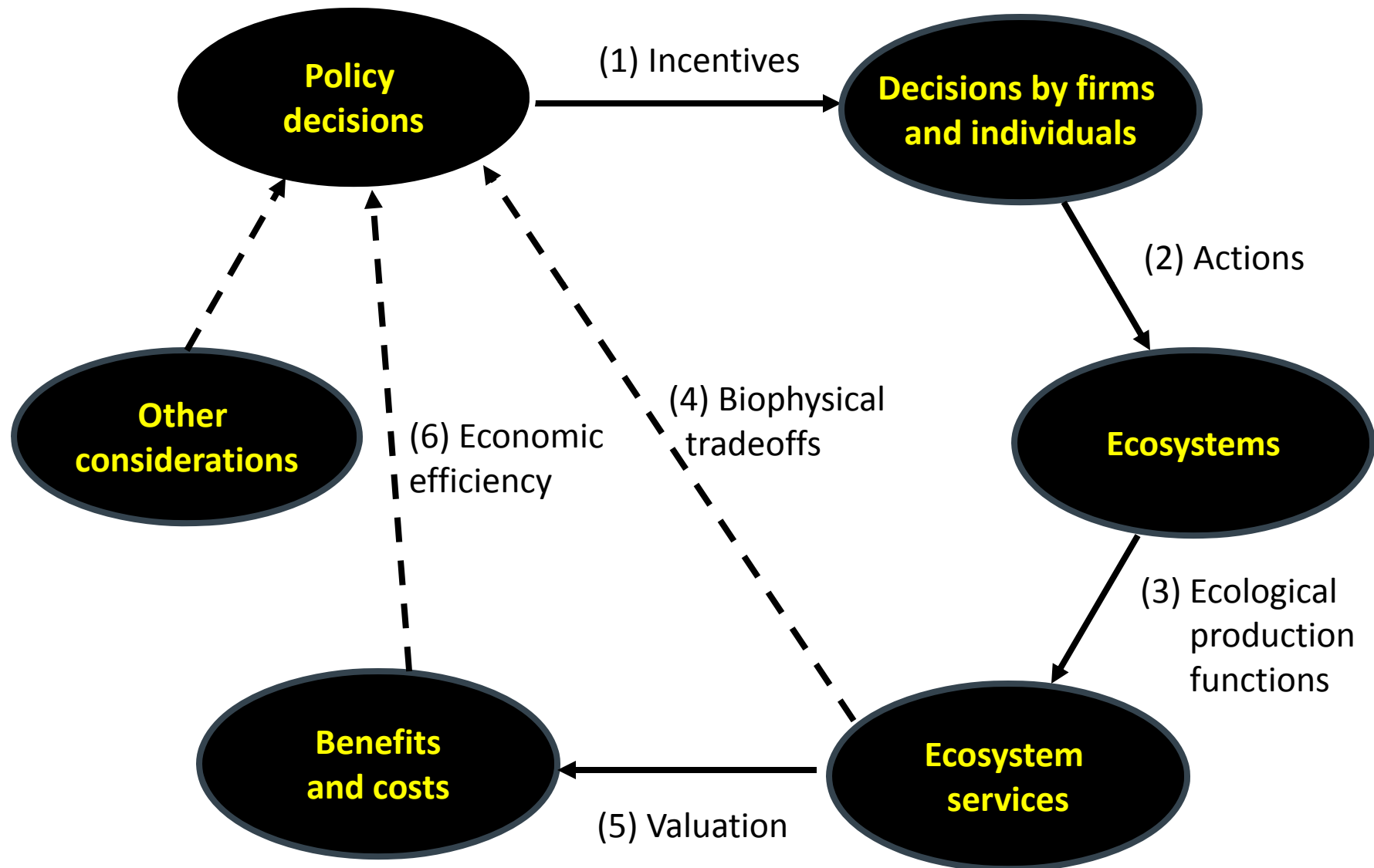
Agricultural prod'n

Irrigation water

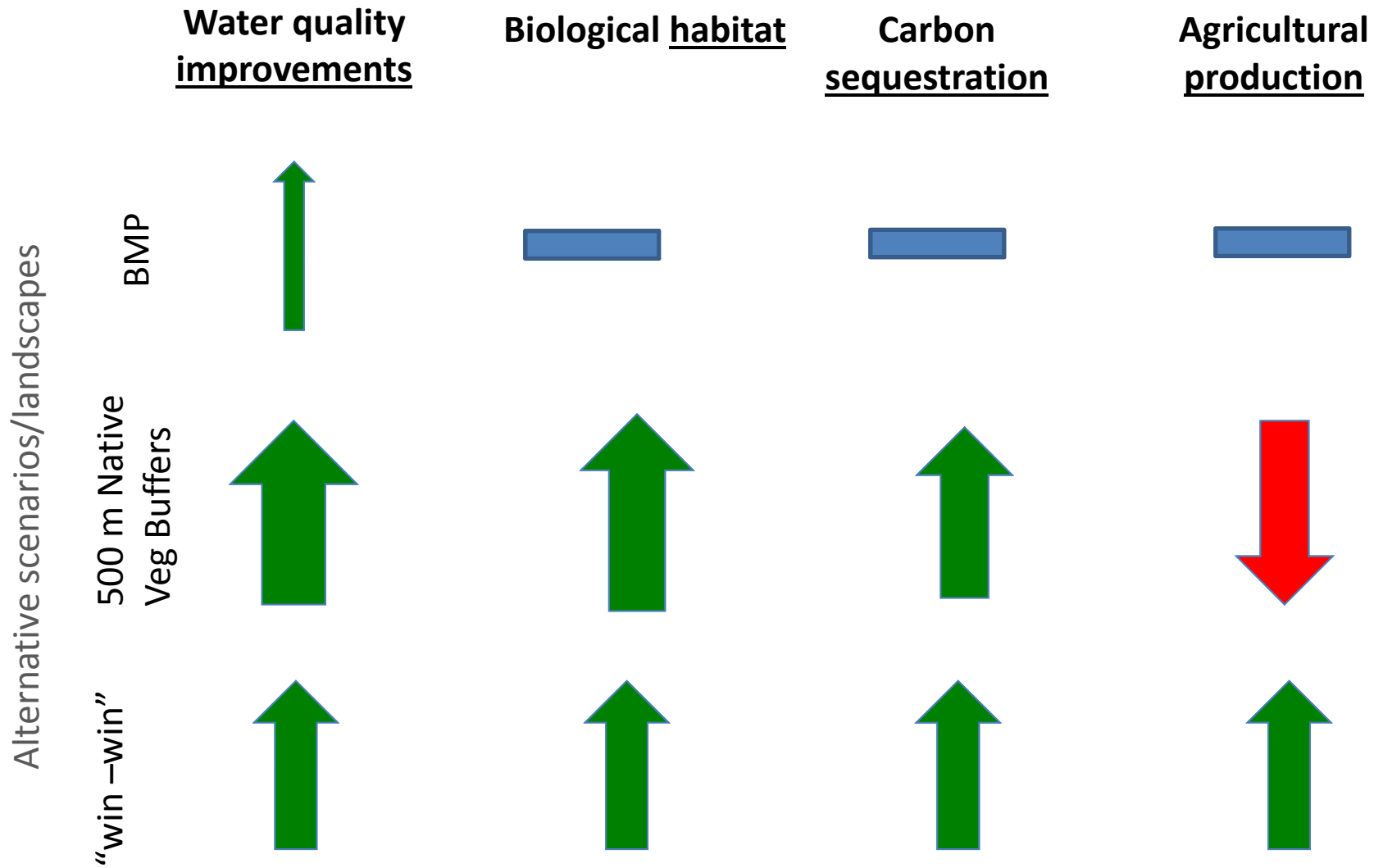
Commercial timber

Flood control

Schematic of ecosystem services research



Evaluating Trade Offs



Study Area: Small Watersheds



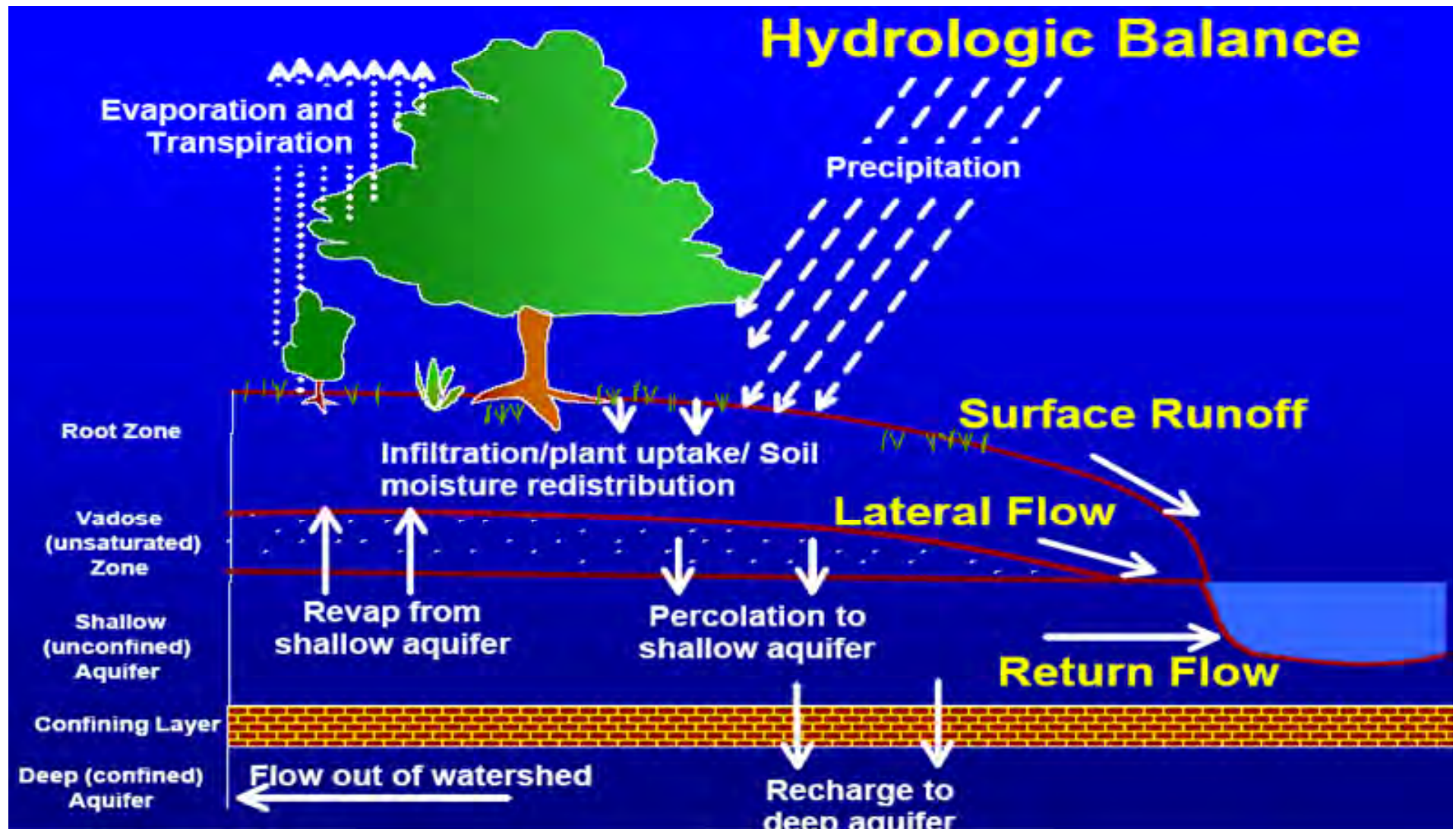


Important non-field
sources of sediment
at the upland/ravine
interface.

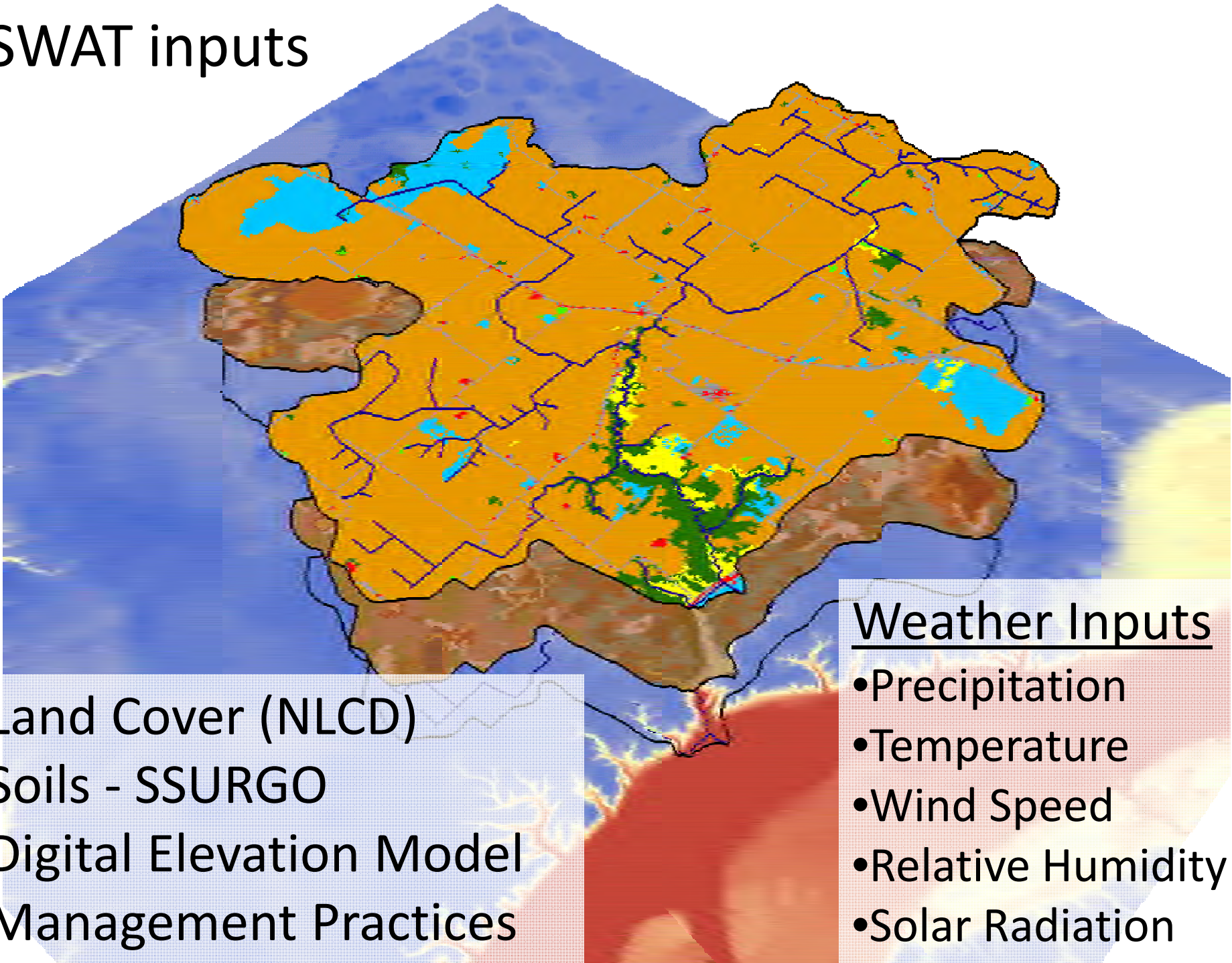


Soil & Water Assessment Tool (SWAT)

Plant Growth, Hydrology, Erosion, Sediment and Nutrients export



SWAT inputs



Land Cover (NLCD)
Soils - SSURGO
Digital Elevation Model
Management Practices

Weather Inputs

- Precipitation
- Temperature
- Wind Speed
- Relative Humidity
- Solar Radiation



WOODS INSTITUTE
FOR THE ENVIRONMENT
STANFORD UNIVERSITY



The Nature
Conservancy



INSTITUTE ON THE
ENVIRONMENT
UNIVERSITY OF MINNESOTA
Driven to Discover

natural
capital
PROJECT

ALIGNING ECONOMIC FORCES WITH CONSERVATION

“InVEST”

Integrated Valuation of Ecosystem Services and Tradeoffs

<http://www.naturalcapitalproject.org/InVEST.html>

SWAT

(biophysical model)

- Crop Yield / Biomass

Field Sources of:

- Sediment
- Phosphorus
- Water

Non-Field Sources of:

- Sediment
- Phosphorus

InVEST

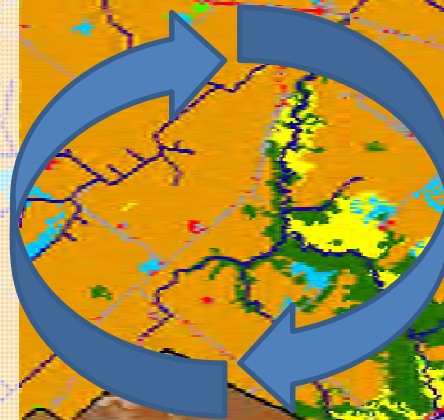
(ecosystem service and valuation model)

Market valuation:

- Crops

Non-market valuation:

- Sediment
- Phosphorus
- Carbon Sequestration

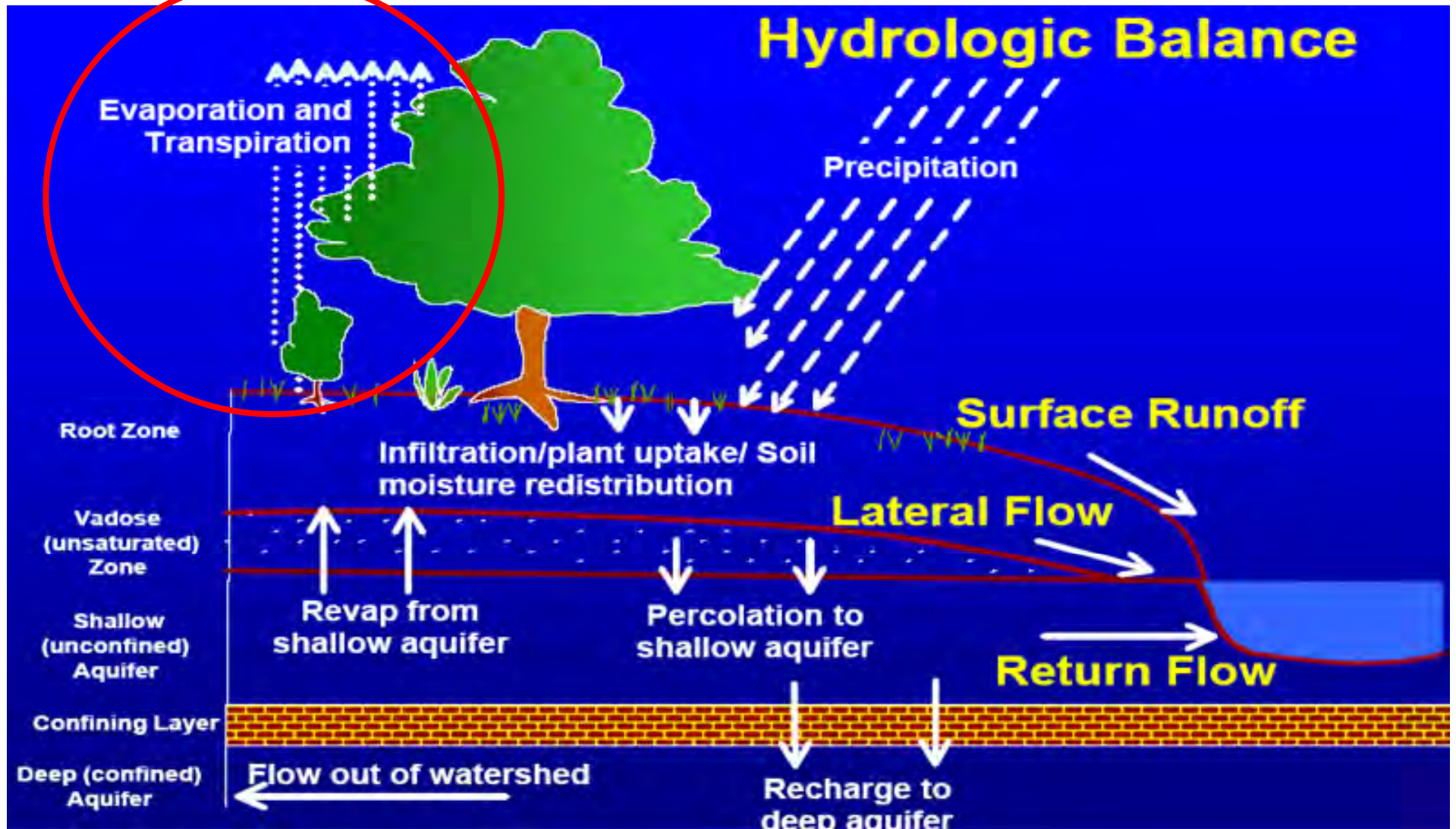


Alternative Scenarios and Landscape Options

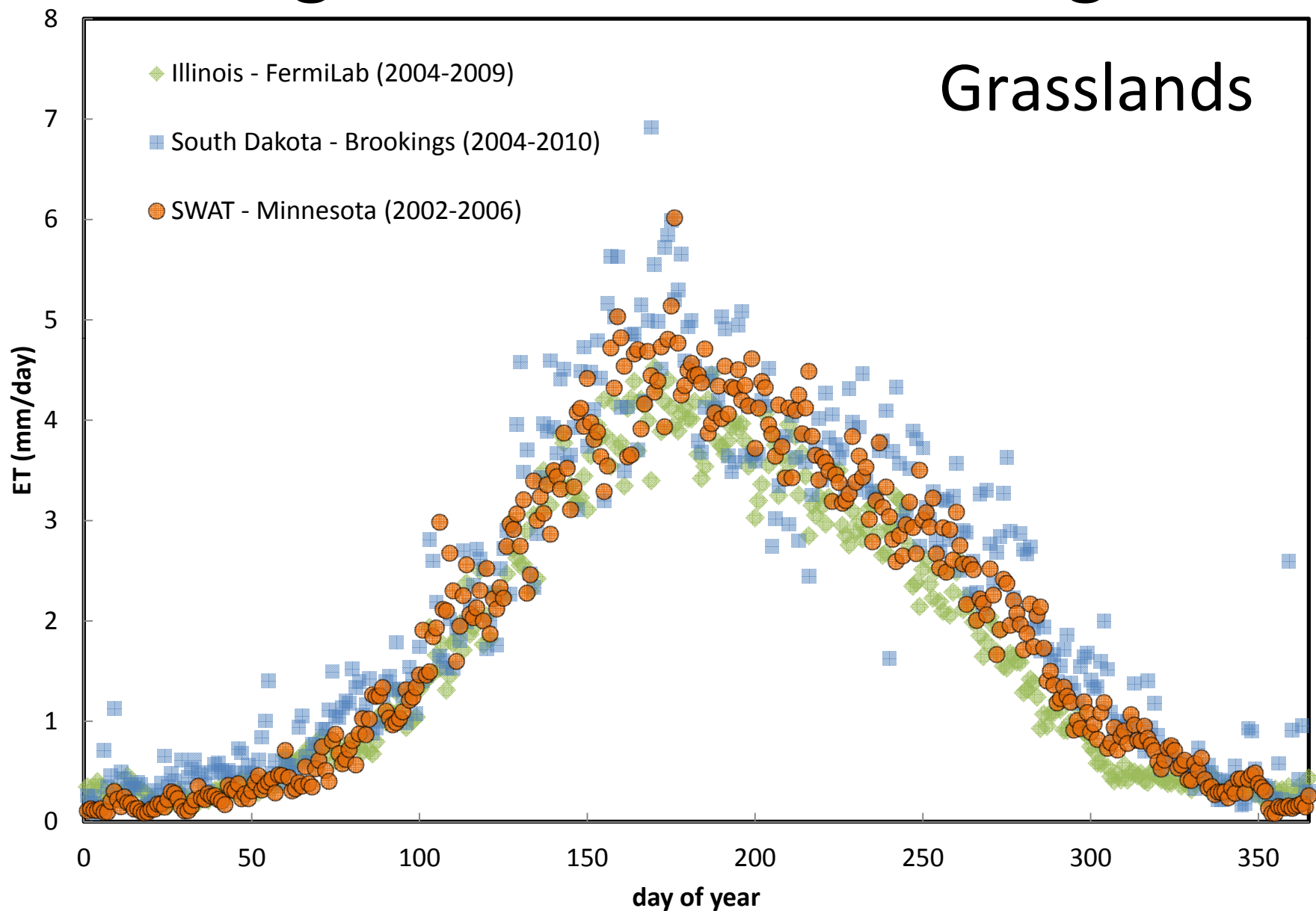
- Conservation Tillage:** Chisel and disk tillage practices are replaced with a conservation tillage practice that leaves 30% residue at time of planting. Field cultivators are still used before planting.
- Reduced P Fertilizer Application:** Fall application of P fertilizer is reduced by 50% from current levels. Manure application is unchanged.
- Cropland Conversion to Grassland:** Biomass is harvested. Previous tile drainage systems remain intact.
- Cropland Conversion to Switchgrass:** Biomass is harvested. Previous tile drainage systems remain intact.
- Cropland Conversion to Forest:** Previous tile drainage systems remain intact.

Model calibration

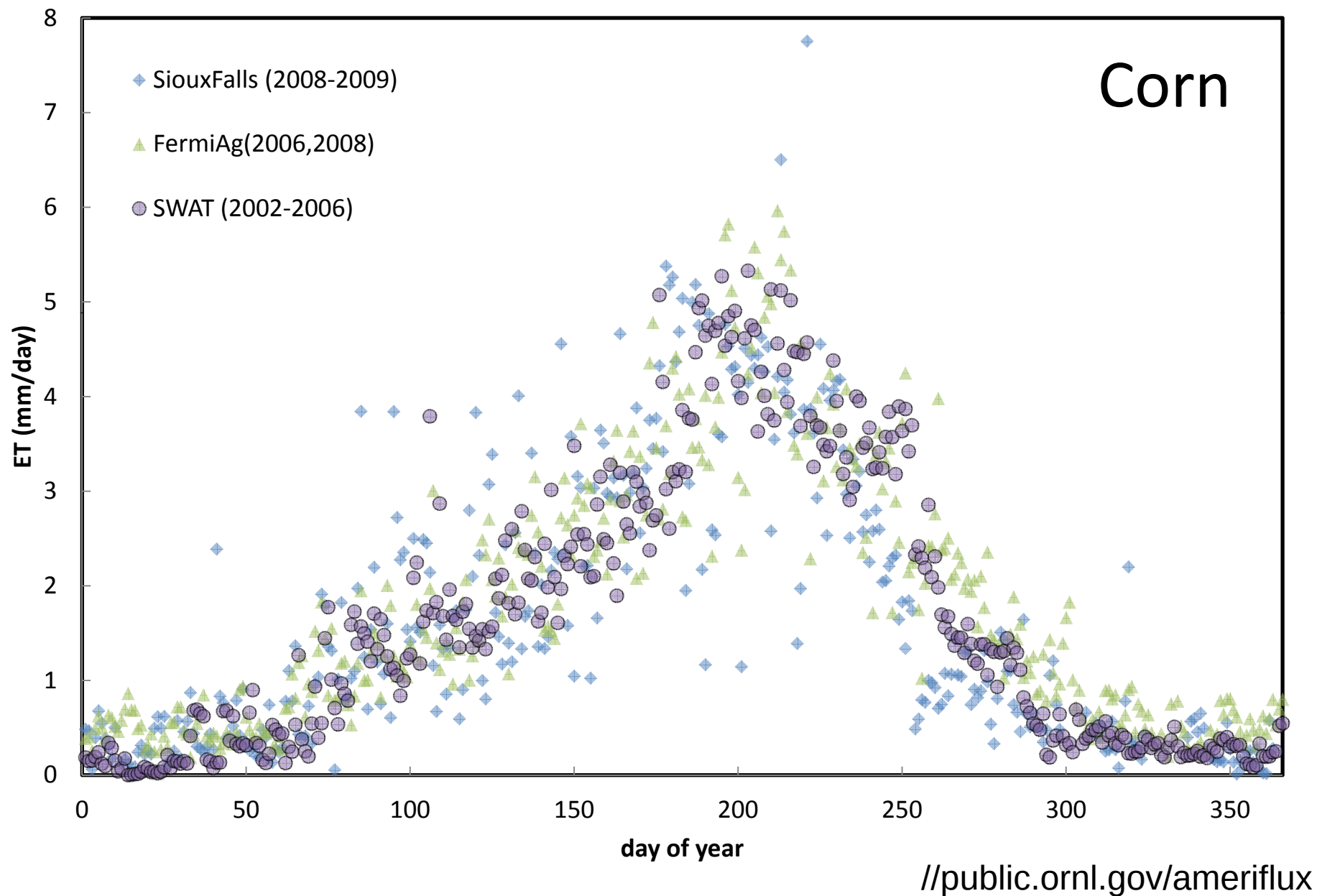
Getting the water balance right...



Getting the water balance right...

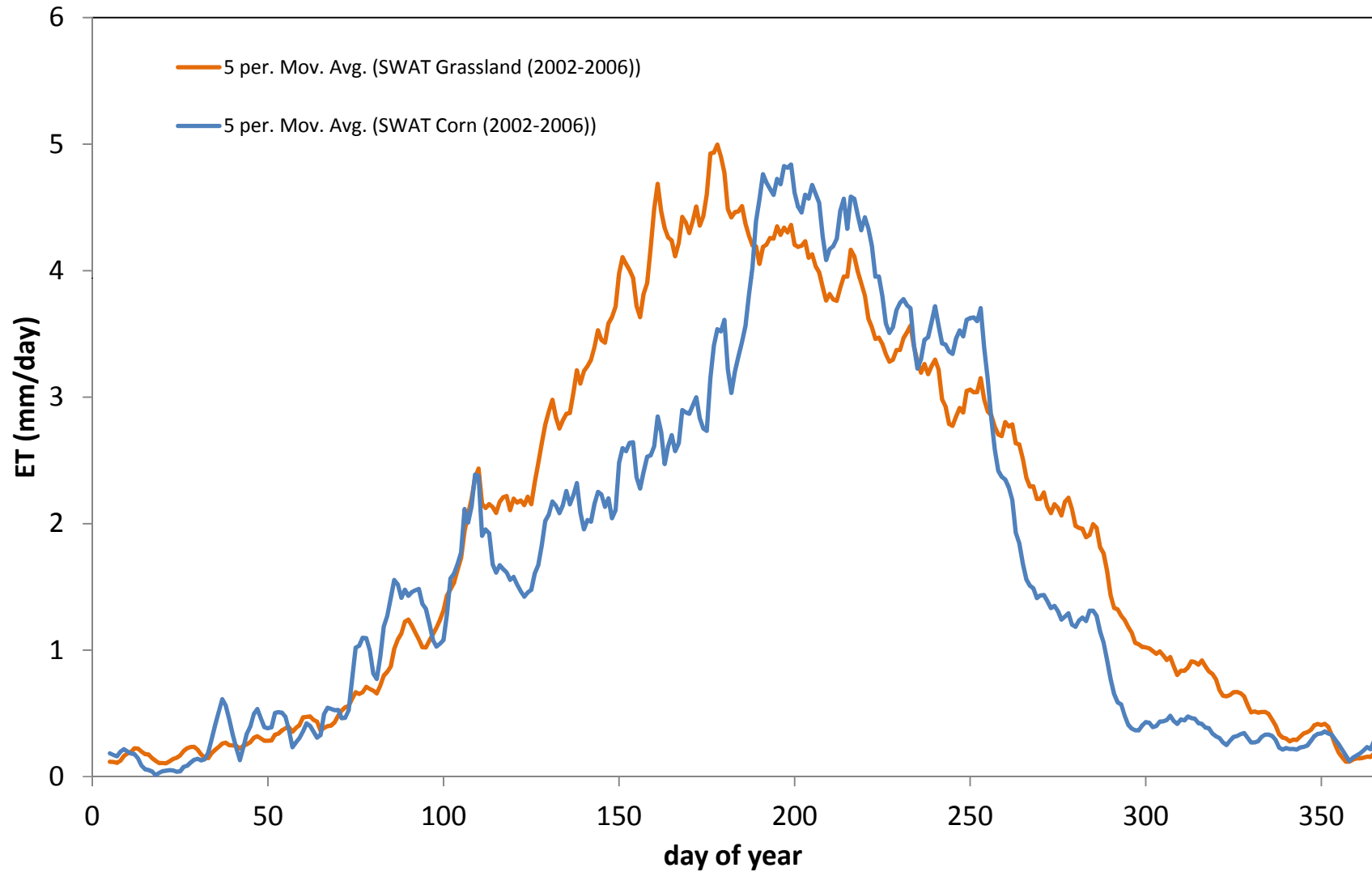


Getting the water balance right...

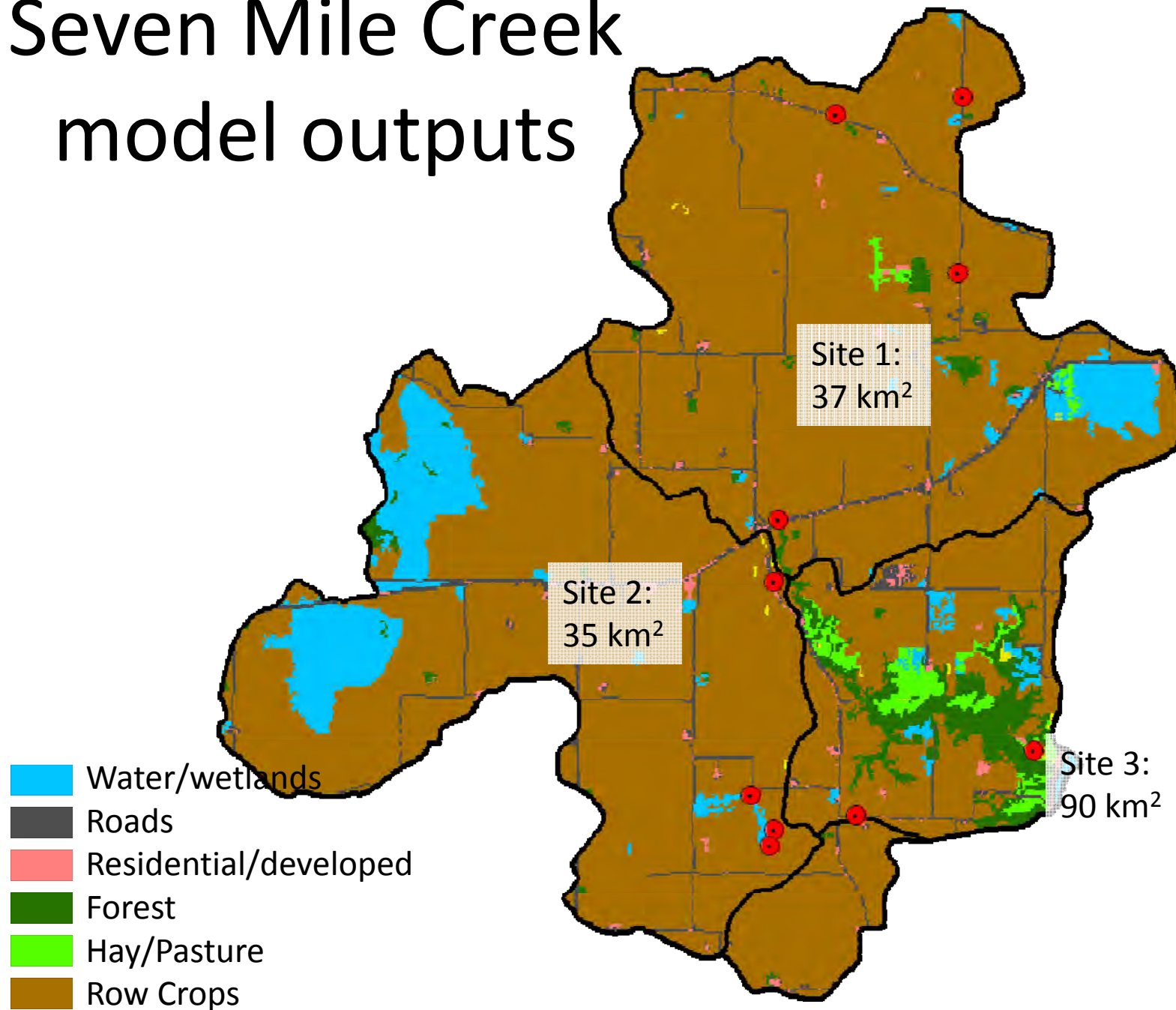


Grasslands-Corn ET comparison

Data from SWAT
output

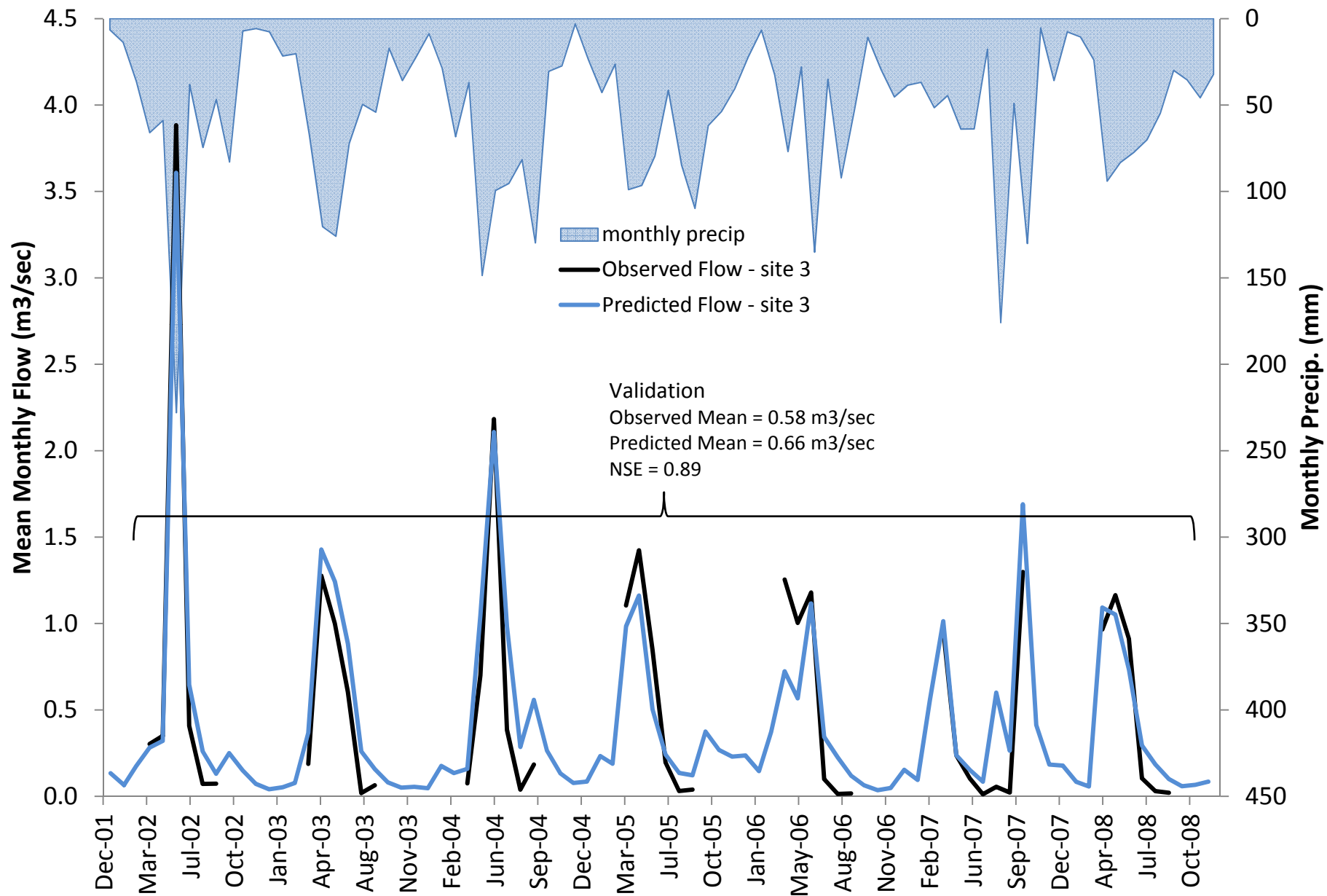


Seven Mile Creek model outputs

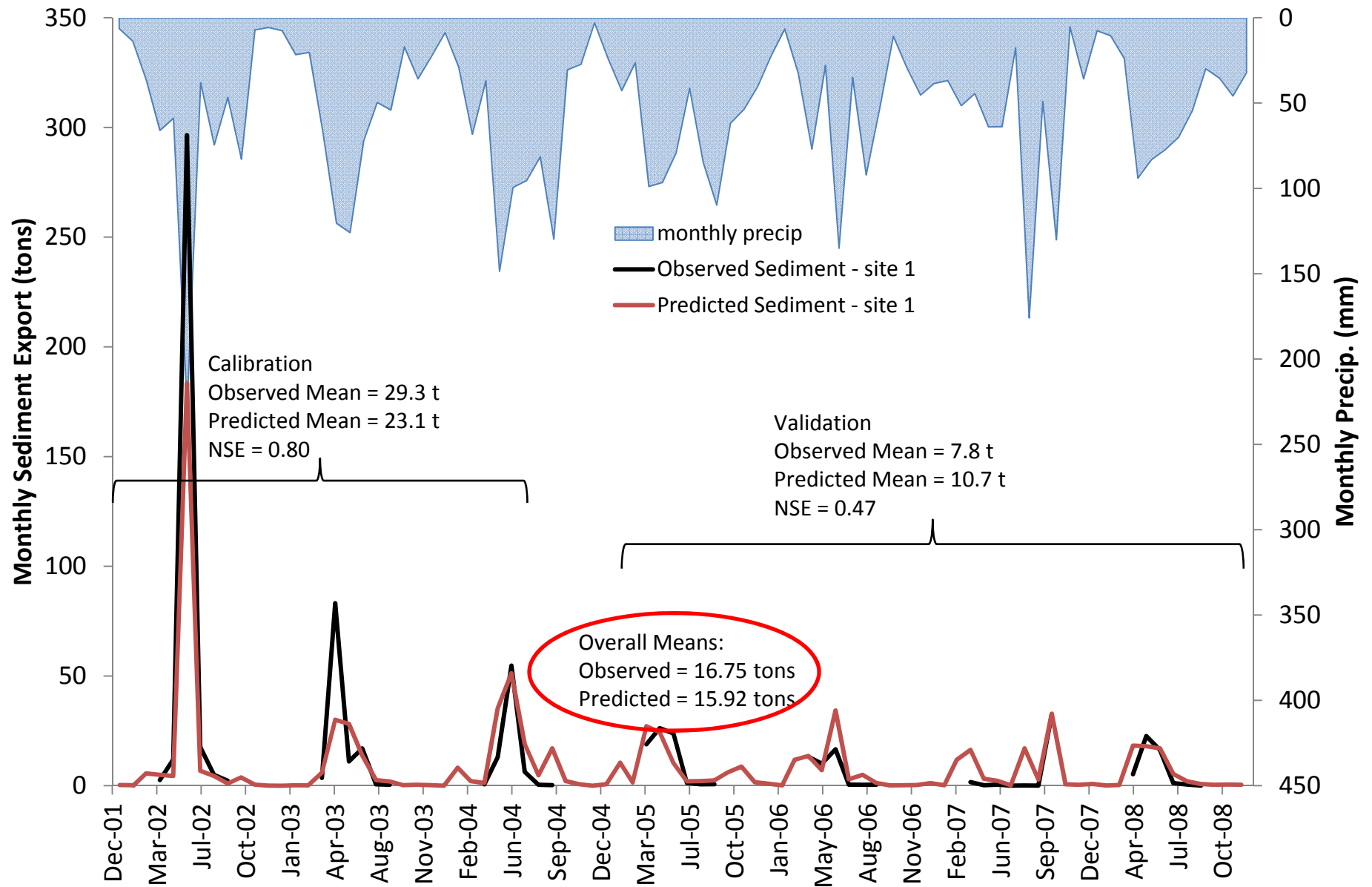


NLCD 2001

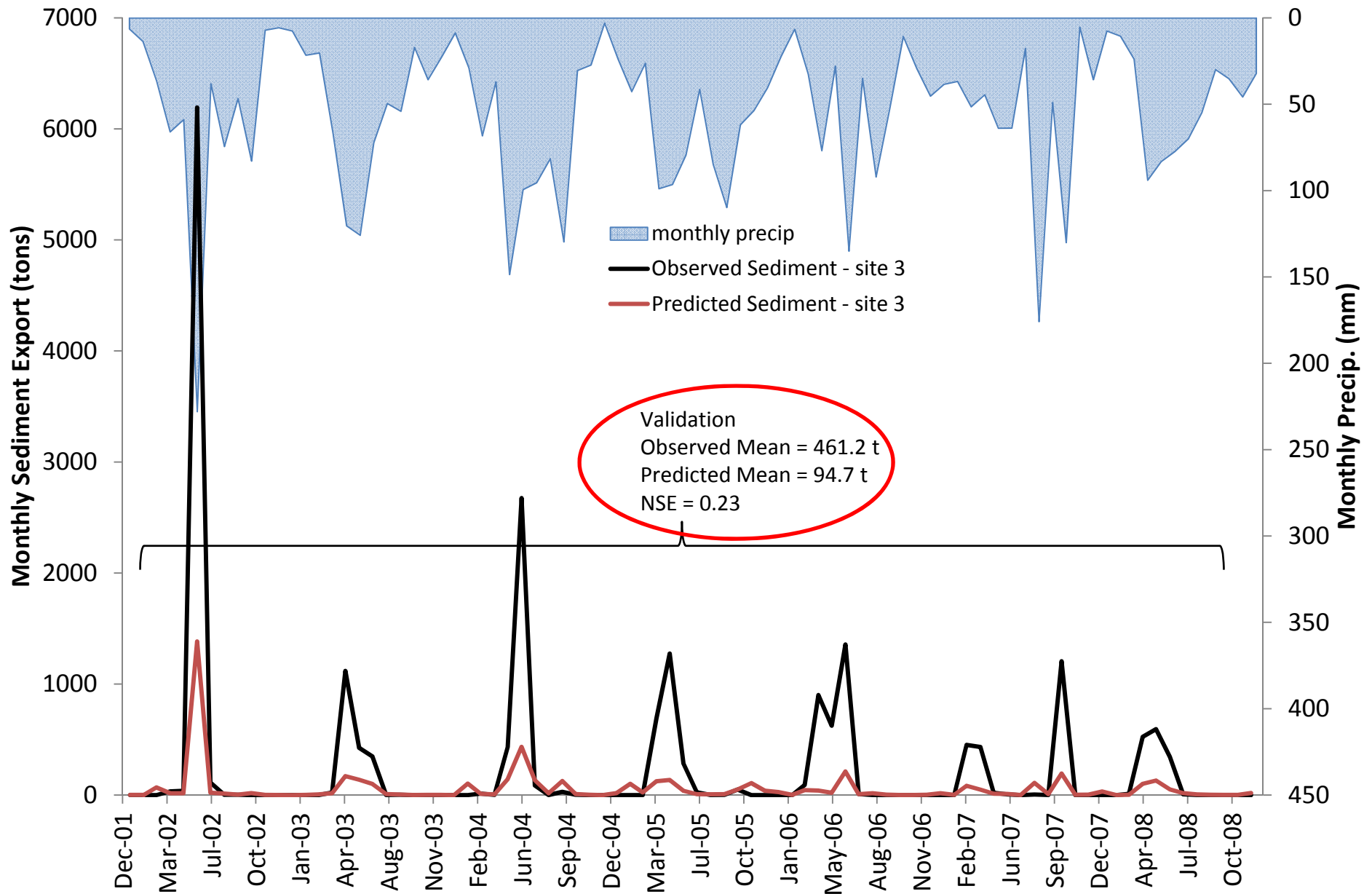
Flow – watershed outlet



Sediment – upland site 1



Sediment – watershed outlet

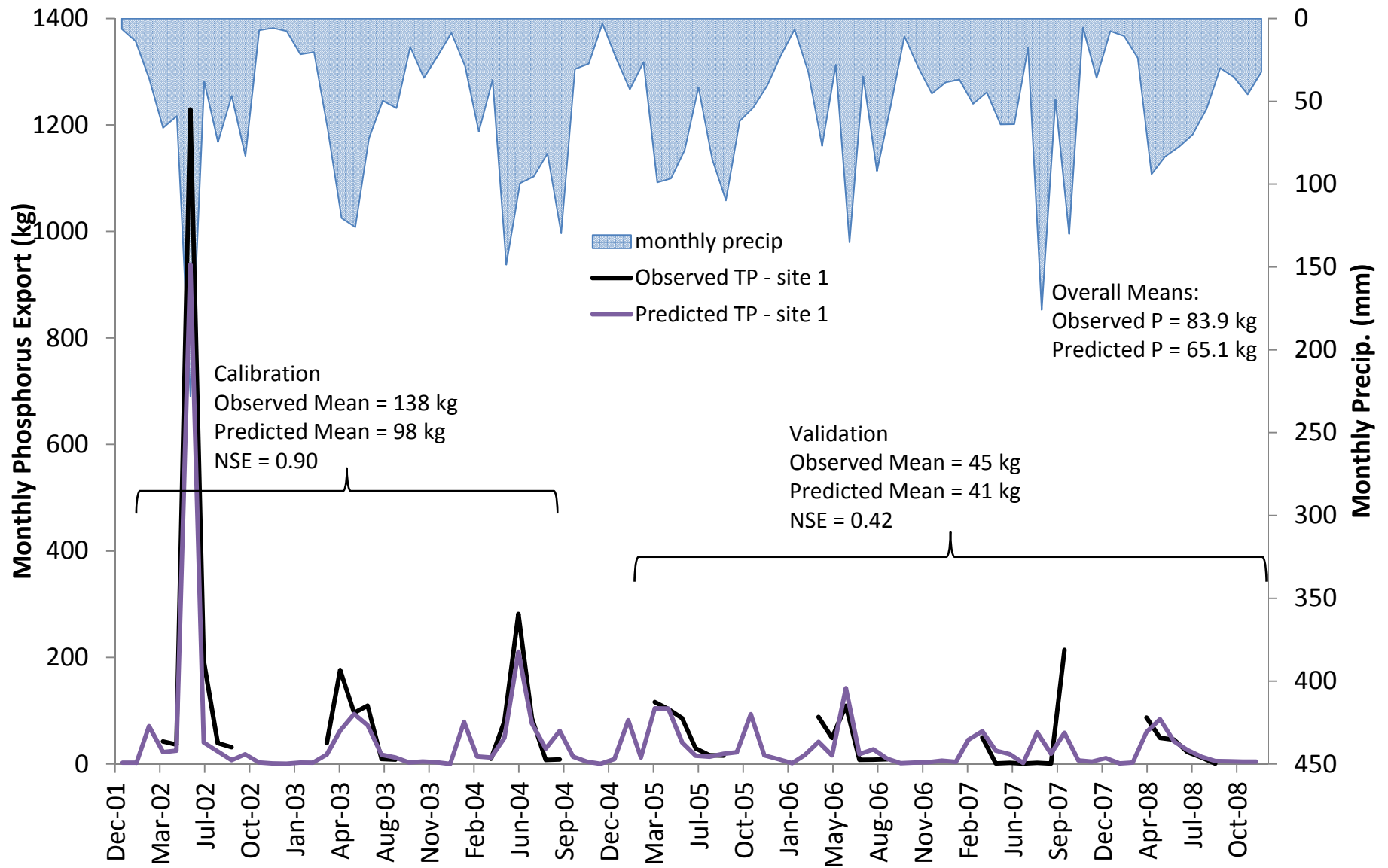




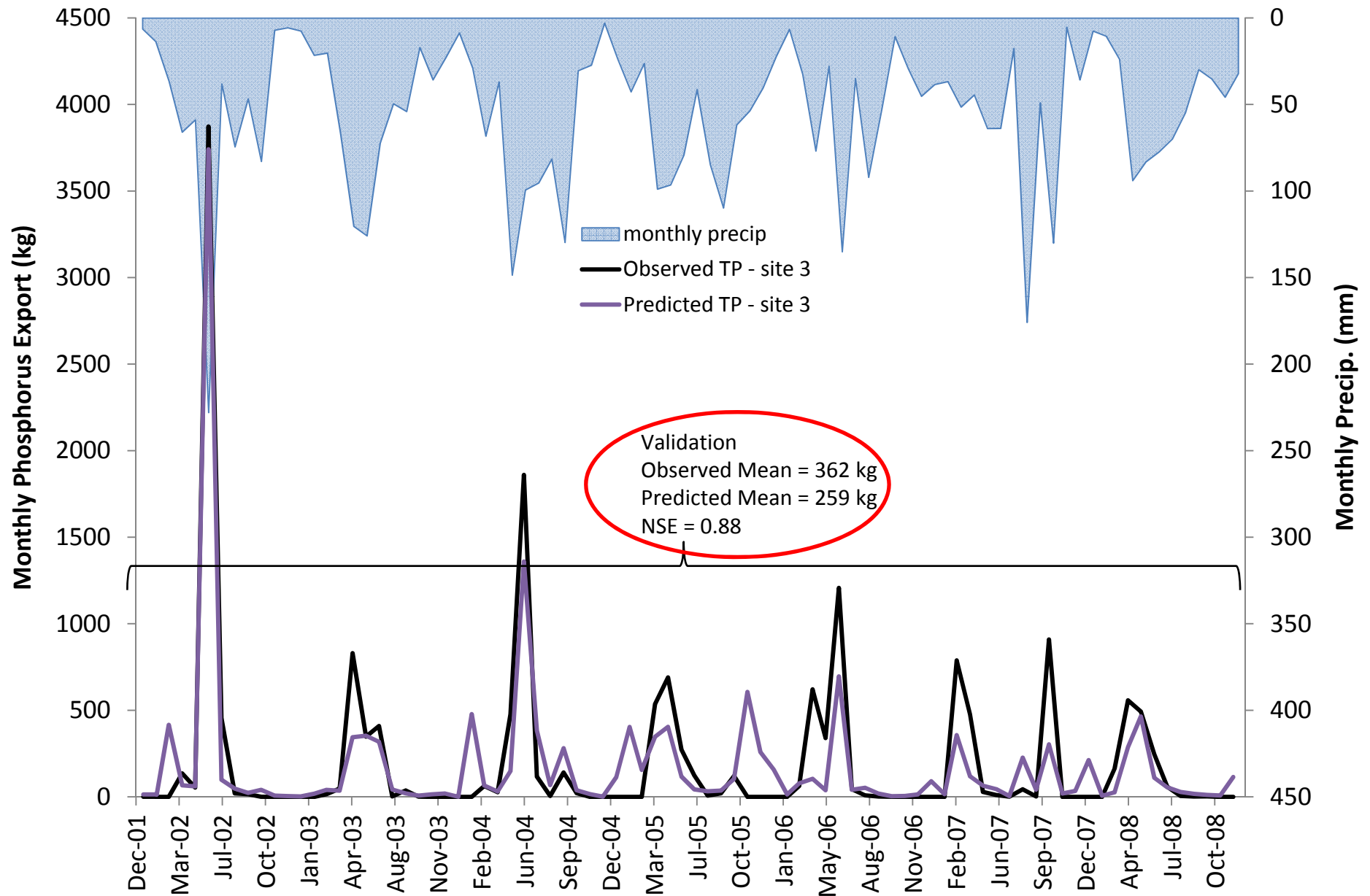
Important non-field sources of sediment at the upland/ravine interface.



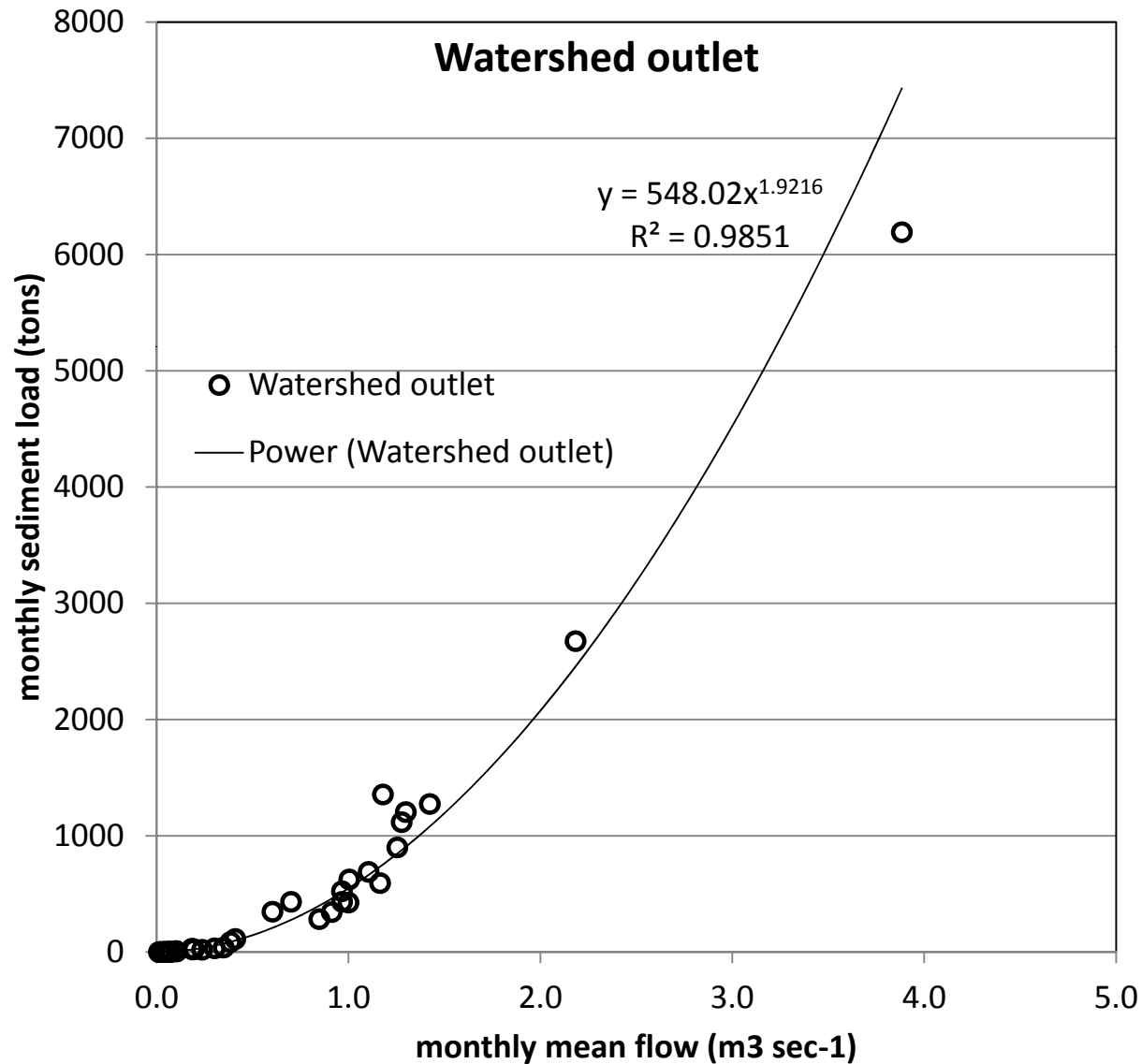
Phosphorus – upland site 1



Phosphorus – watershed outlet

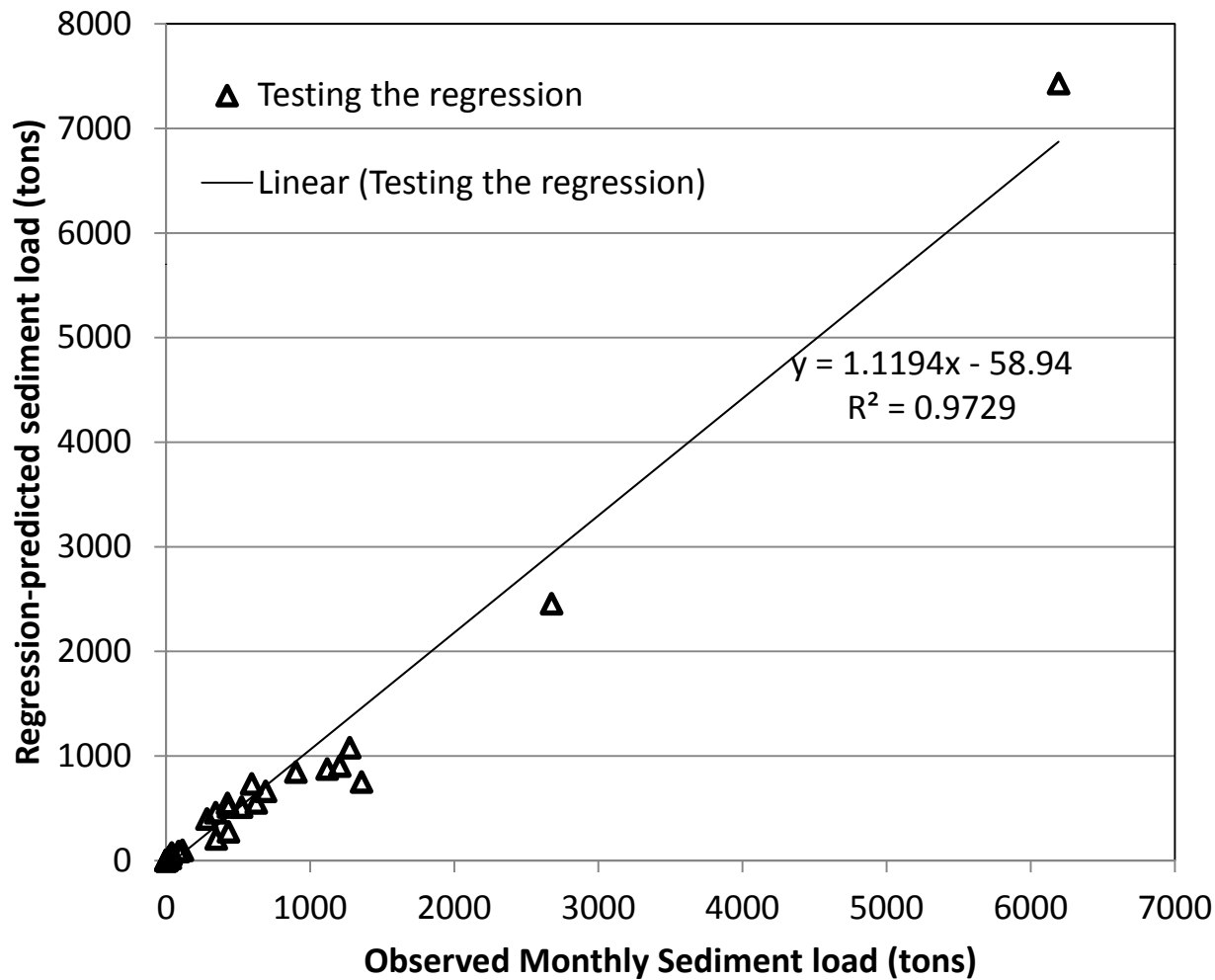


Flow-Sediment relationship at watershed outlet

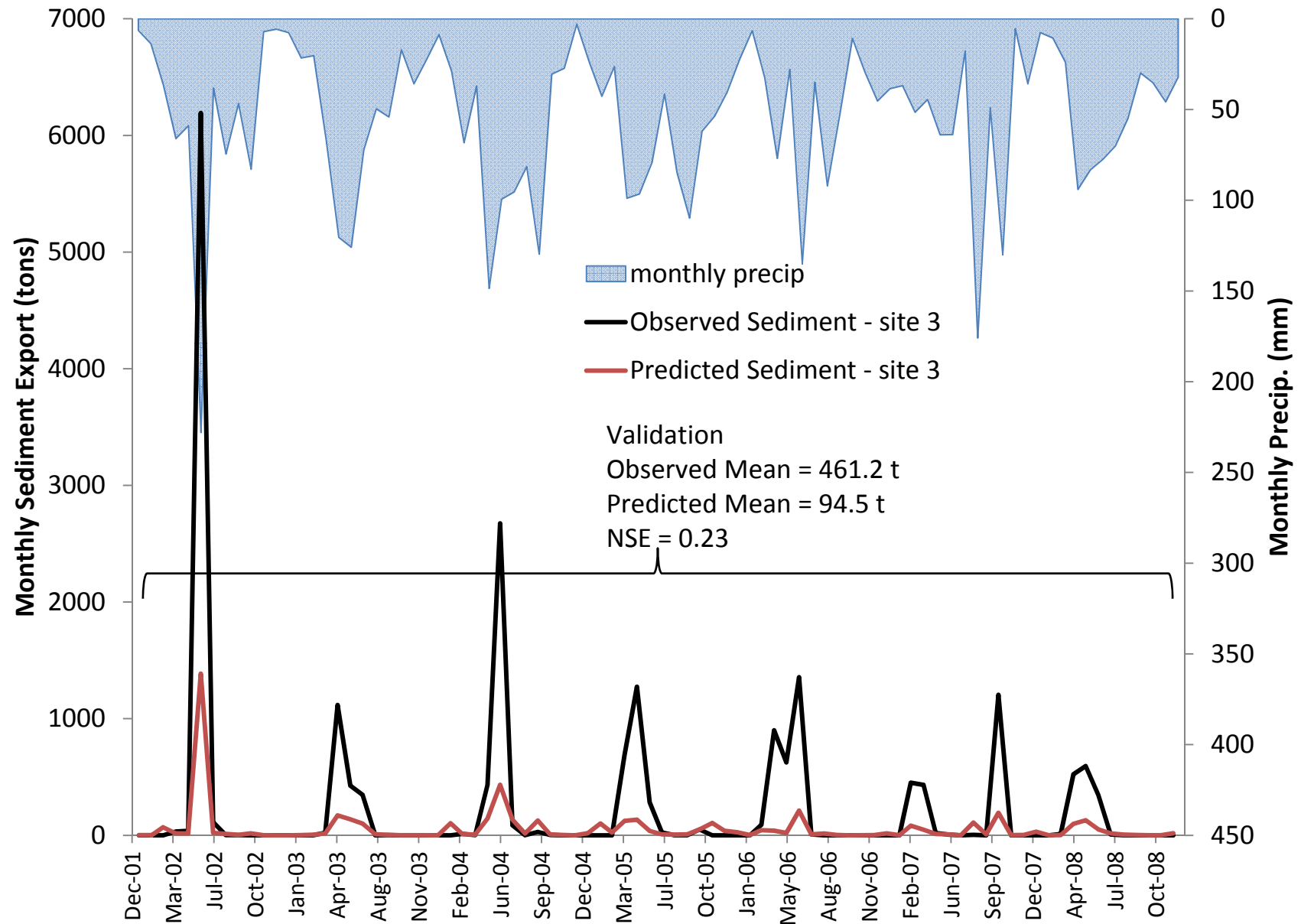


Comparison of observed and regression-predicted monthly sediment loads.

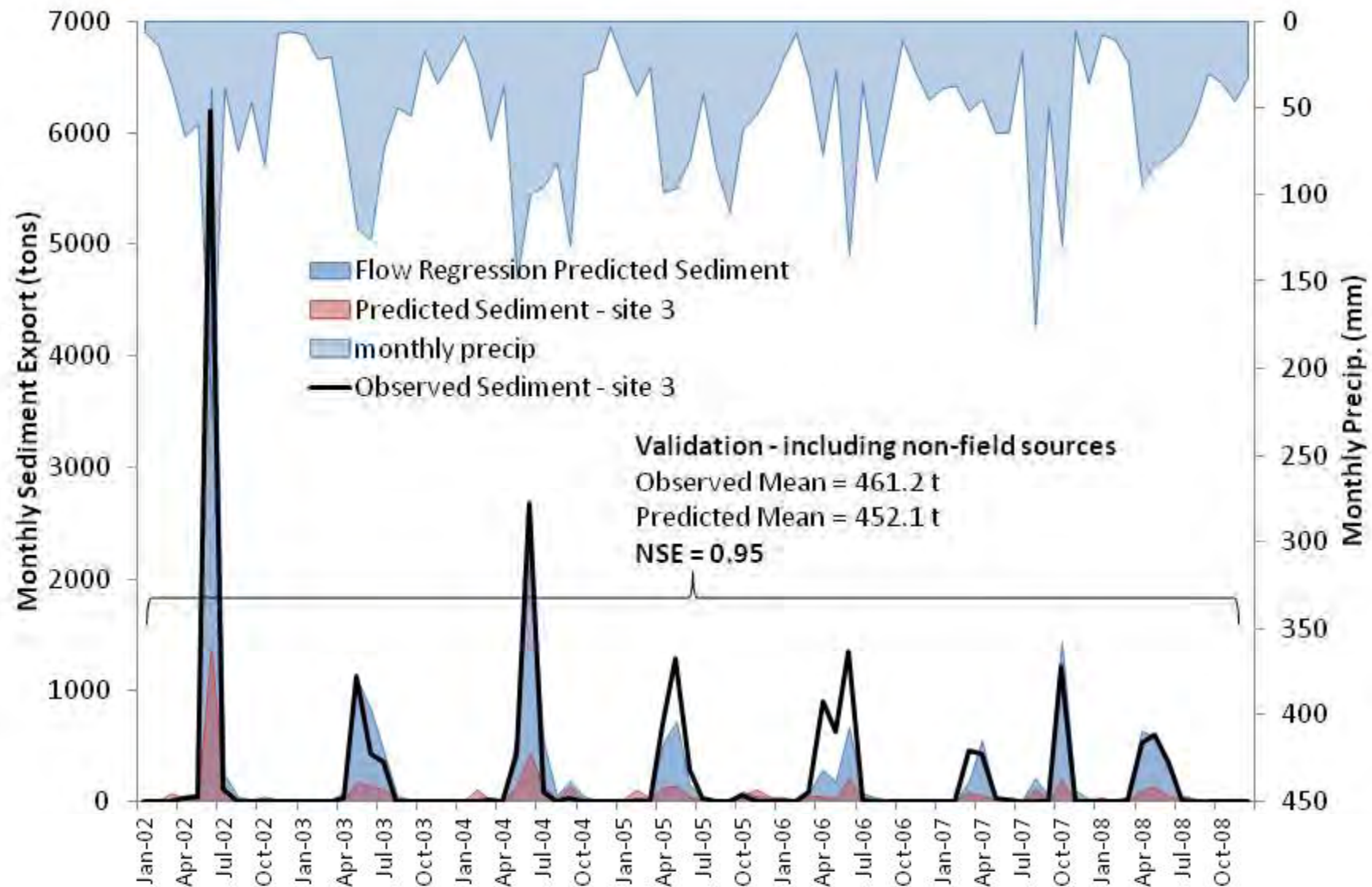
Testing the regression



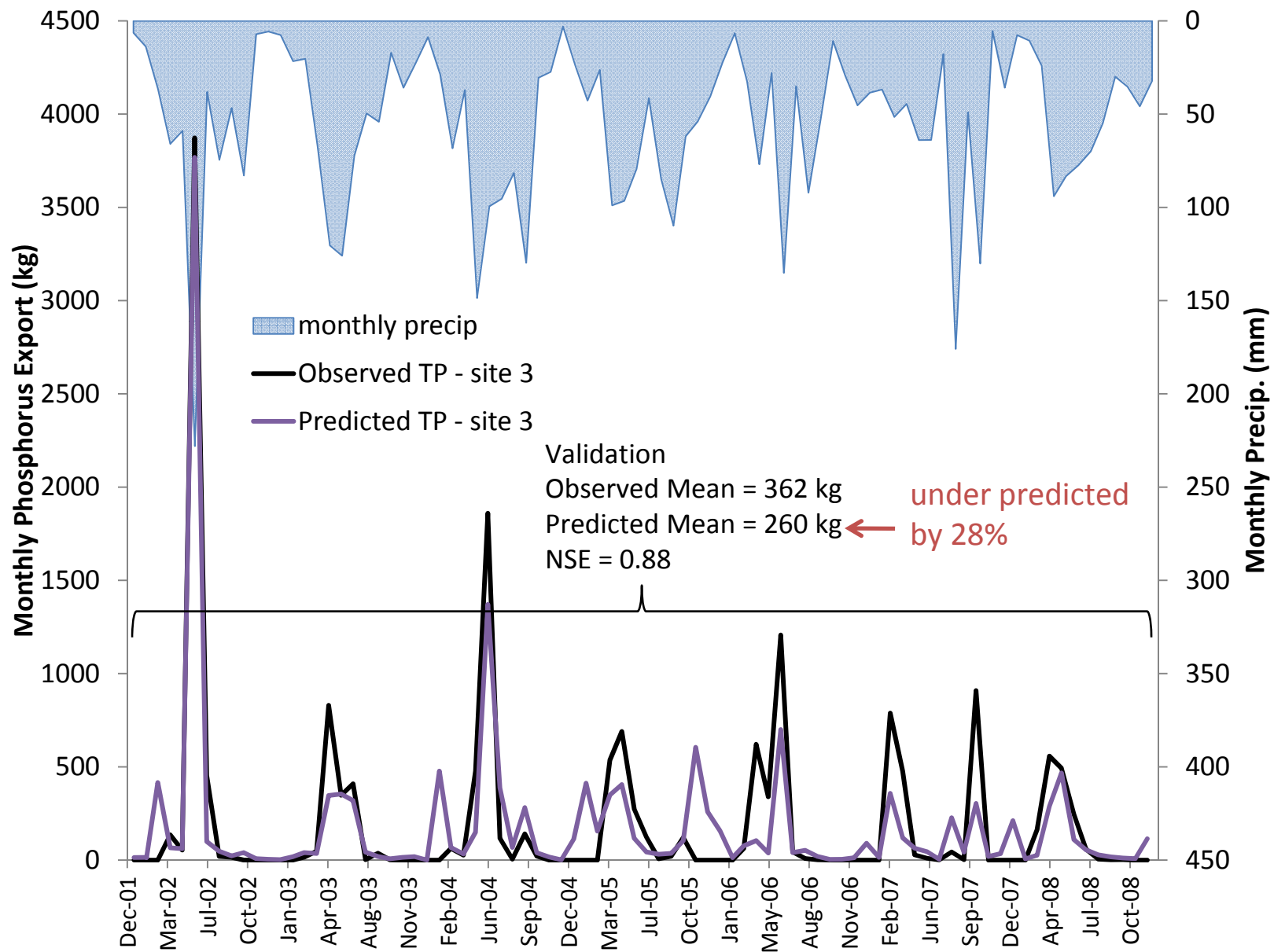
SWAT-predicted sediment from field sources



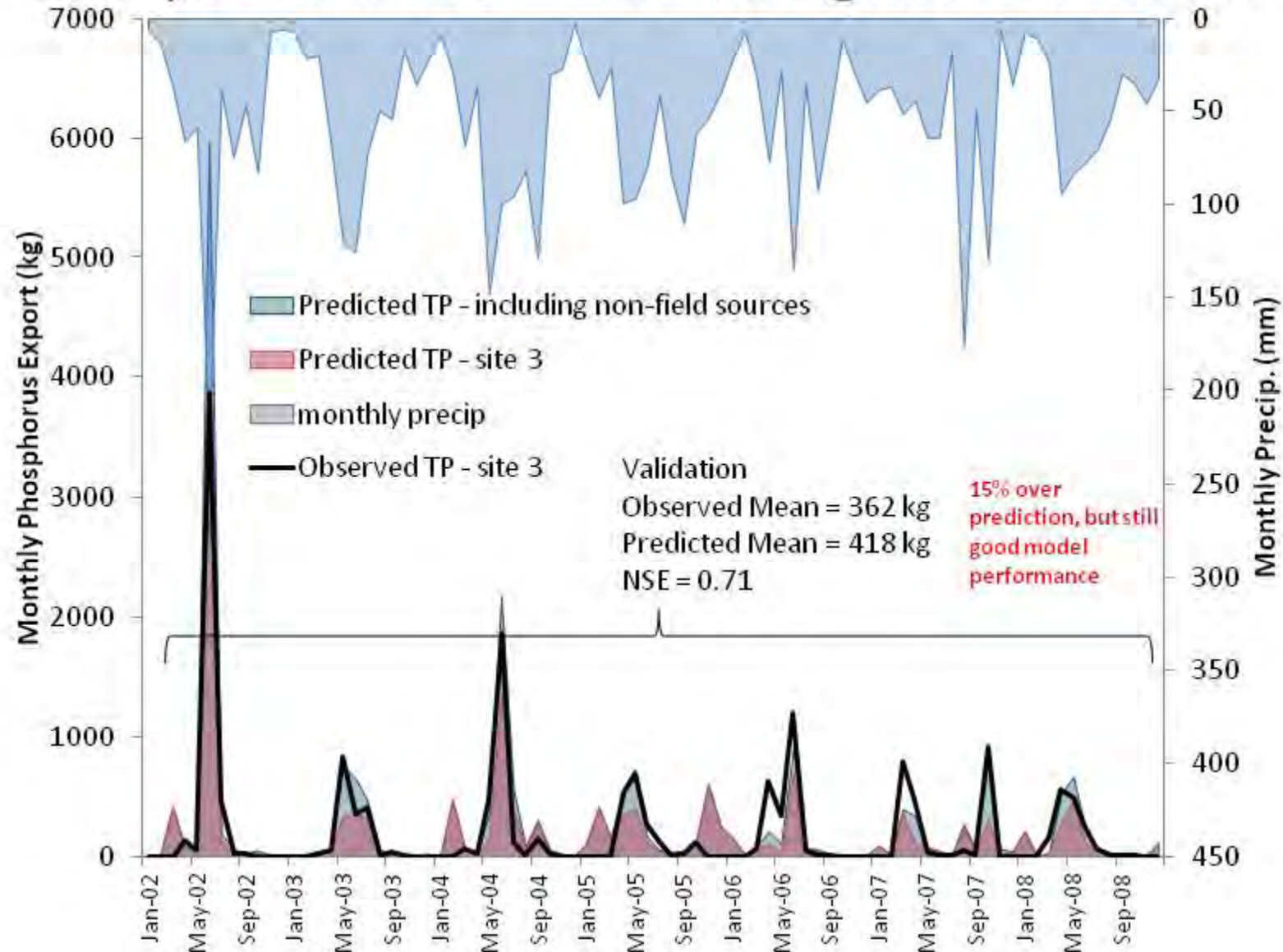
Model performance – including non-field sources



SWAT-predicted phosphorus from field sources

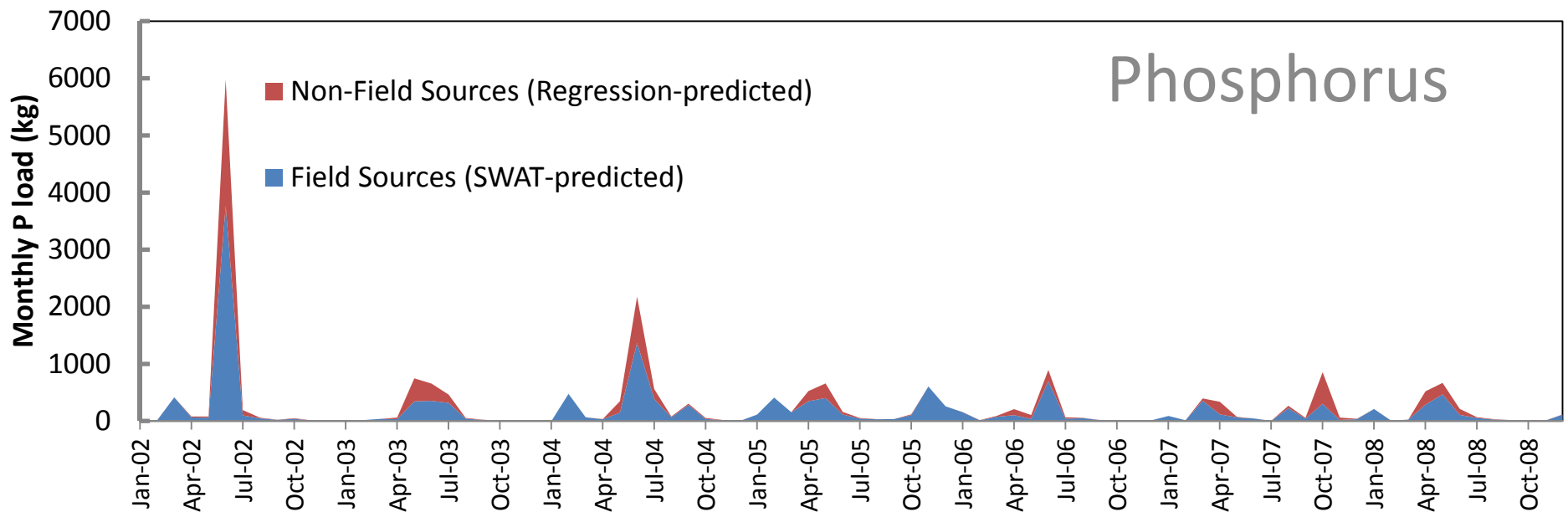
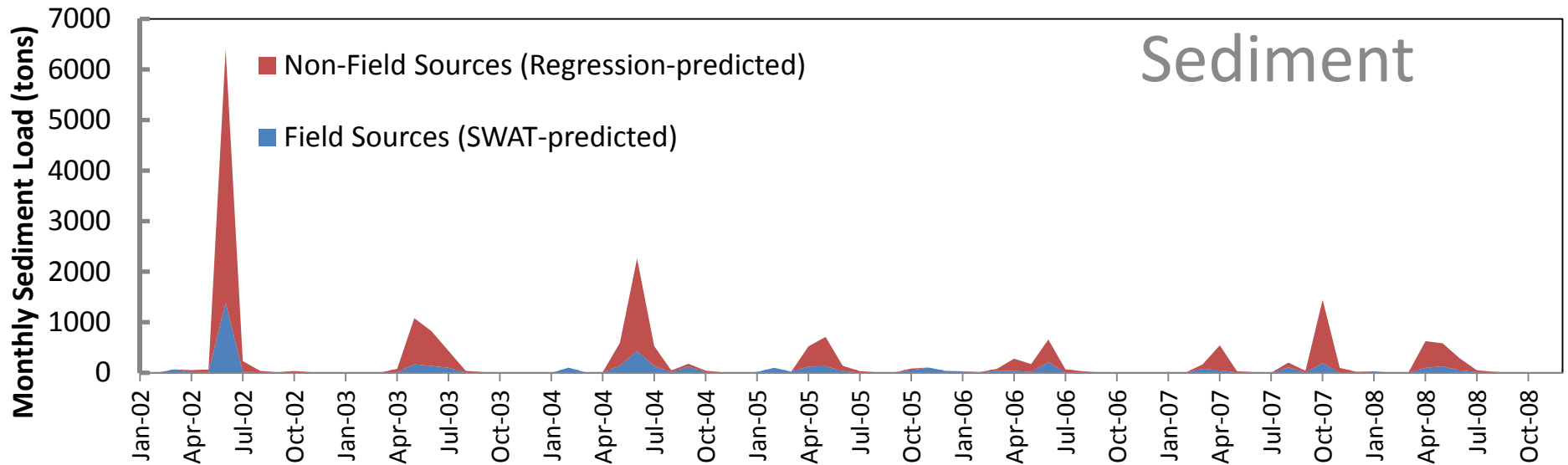


Model performance – including non-field sources



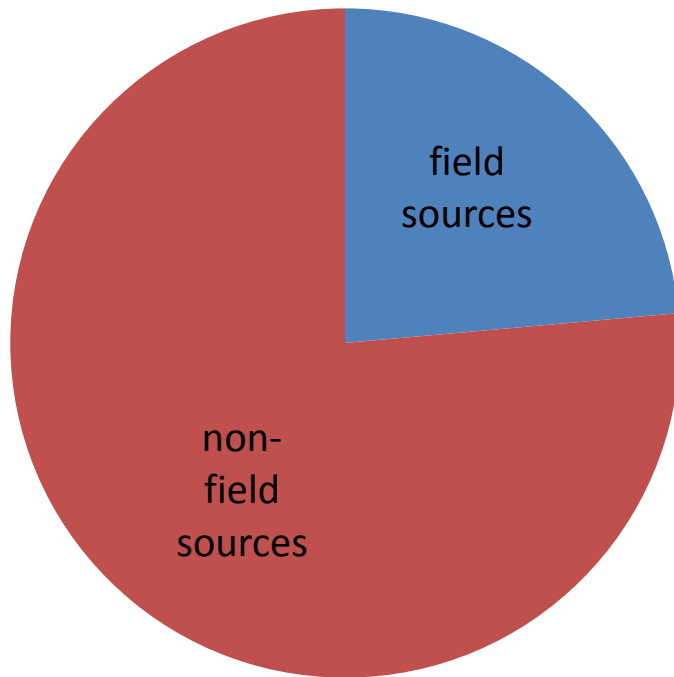
Assumes P content of streambank sediment is 441ppm after Sekely et al., (2002)

Summary of sediment and phosphorus sources

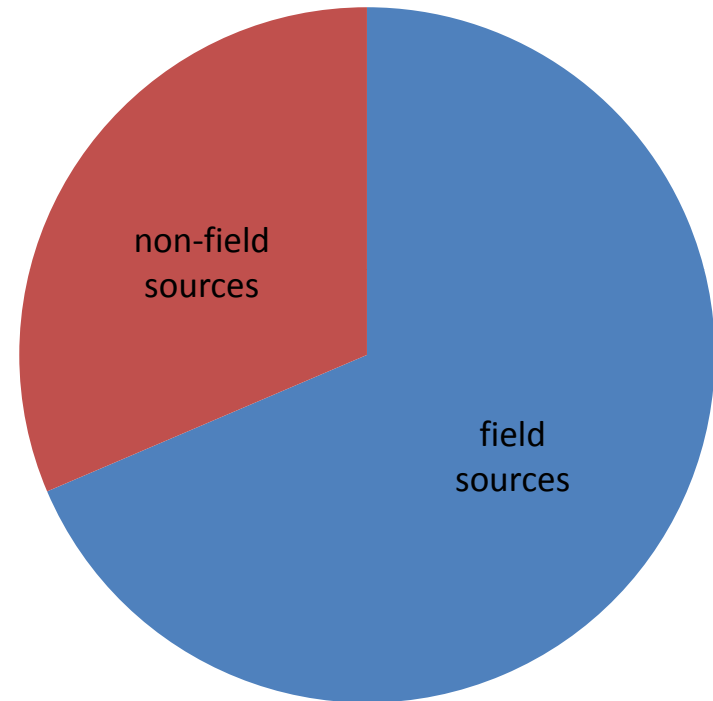


Average distribution of sediment and phosphorus sources

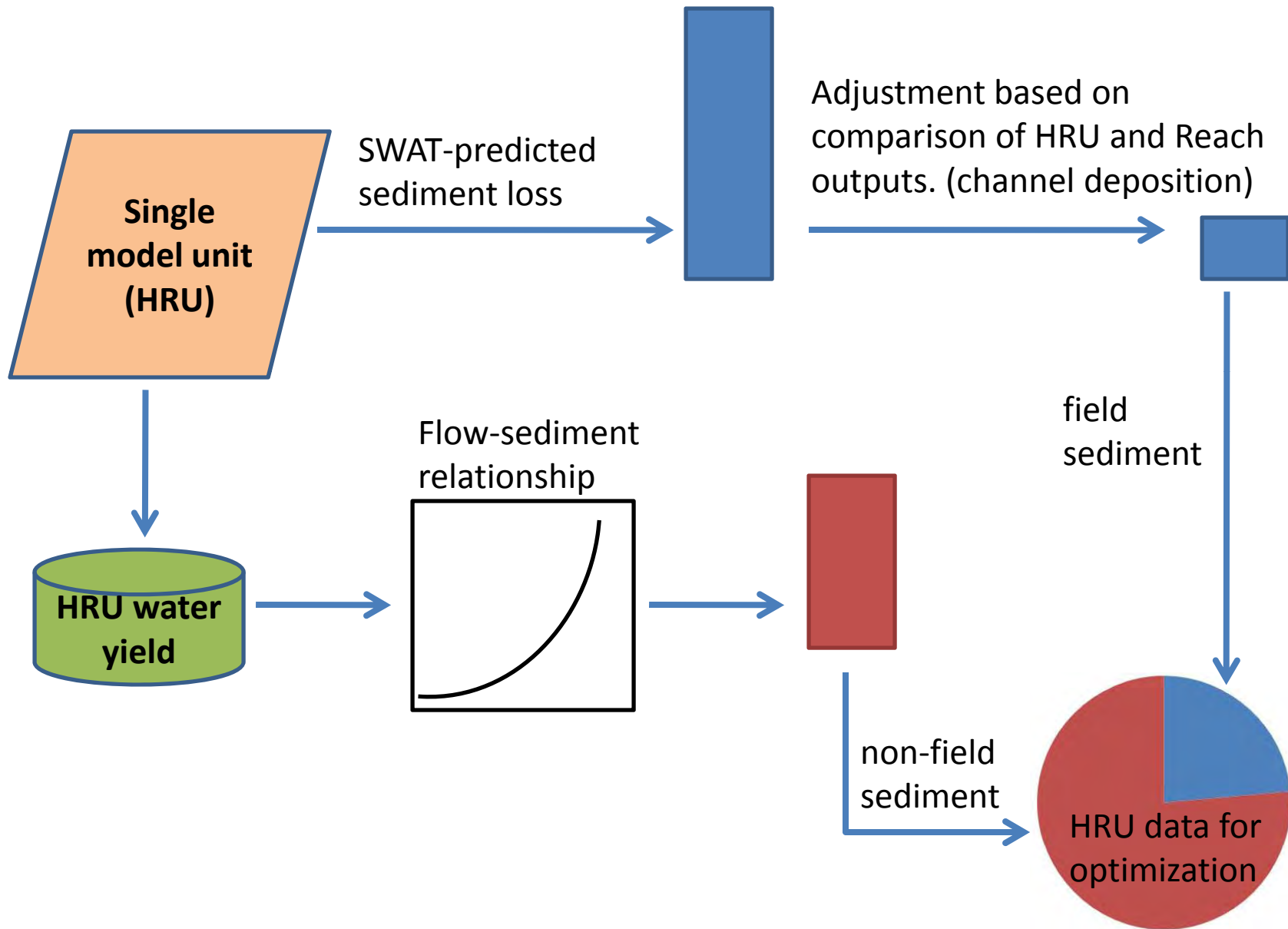
Sediment



Phosphorus



Data preparation schematic for optimization input



Optimization Methods

The quest for the Efficiency Frontier

SWAT

(biophysical model)

- Crop Yield / Biomass

Field Sources of:

- Sediment
- Phosphorus
- Water

Non-Field Sources of:

- Sediment
- Phosphorus

InVEST

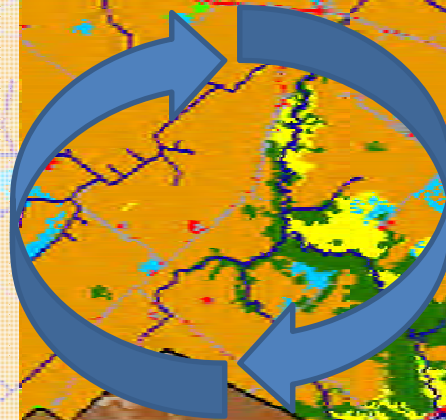
(ecosystem service and valuation model)

Market valuation:

- Crops

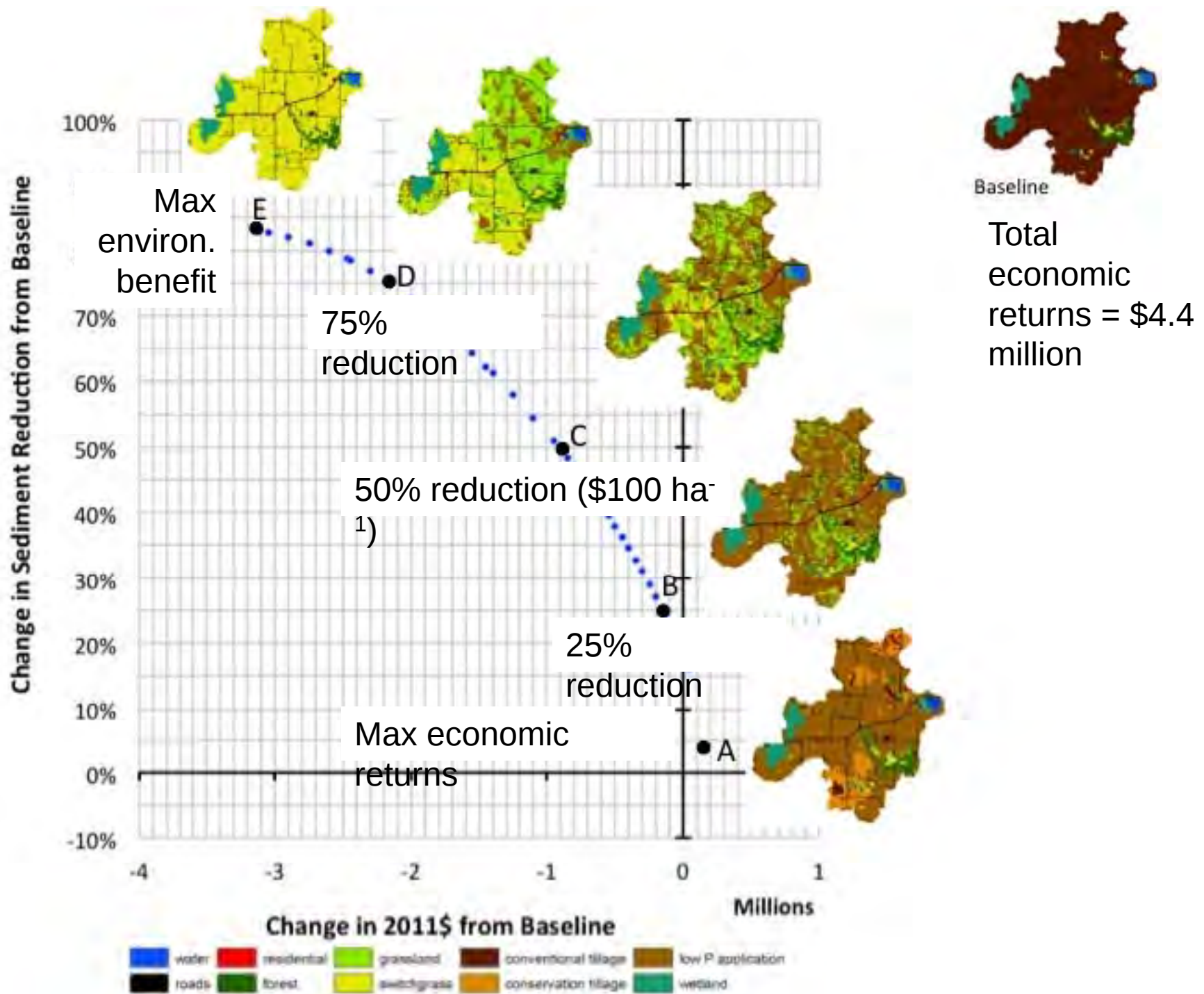
Non-market valuation:

- Sediment
- Phosphorus
- Carbon Sequestration



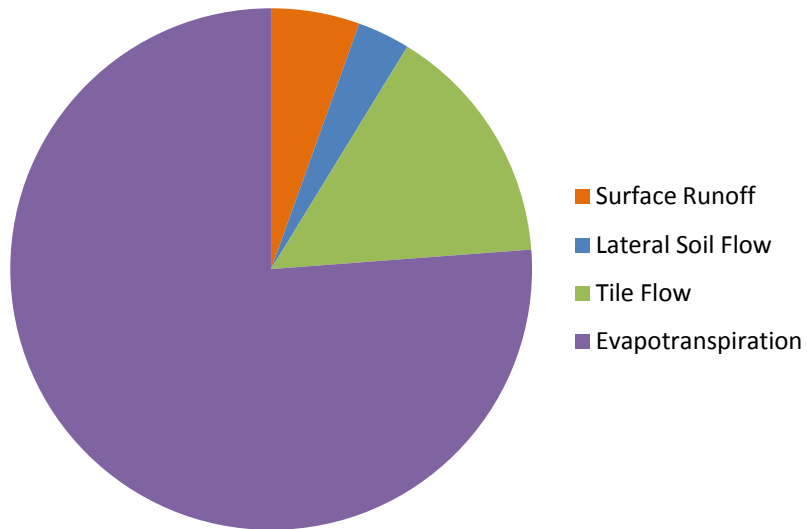
Optimization Methods

- The goal of the analysis is to find land-use patterns that maximize the watershed TMDL reductions for a given watershed economic return, and vice versa
- We combine results from the biophysical and economic models to search for these efficient land-use patterns
- By finding the maximum TMDL reduction for a fixed economic score, and then varying the economic score over its entire potential range, we trace out the efficiency frontier

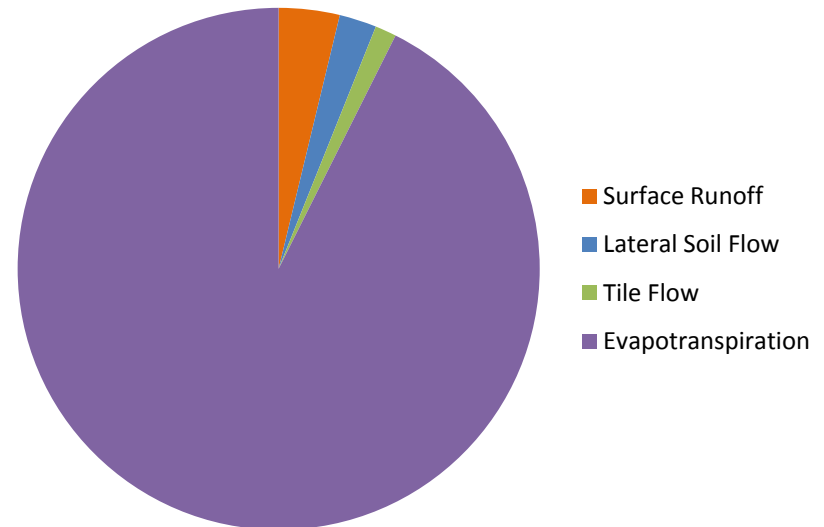


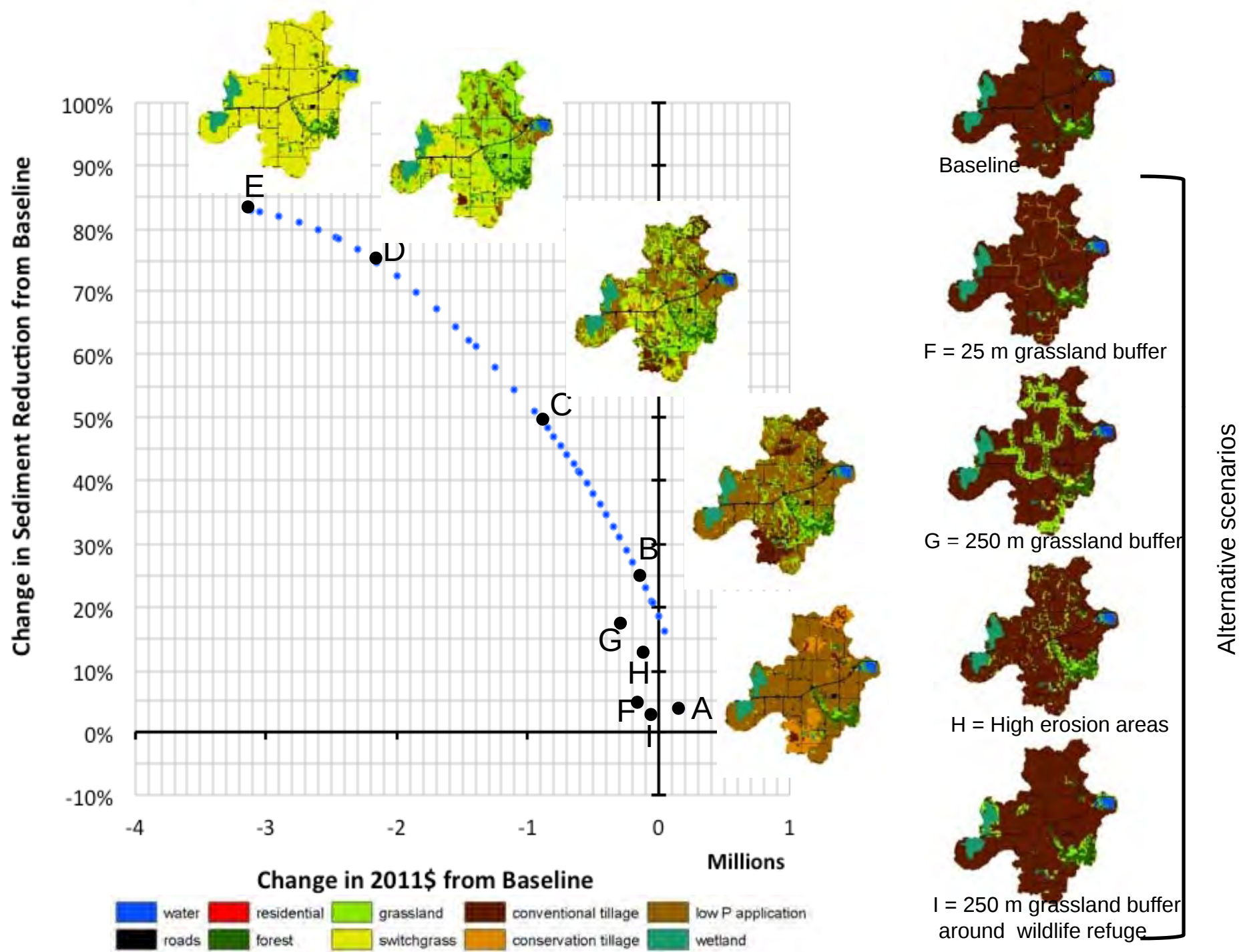
Water Budget Comparison

Water Budget - Baseline (row crop)

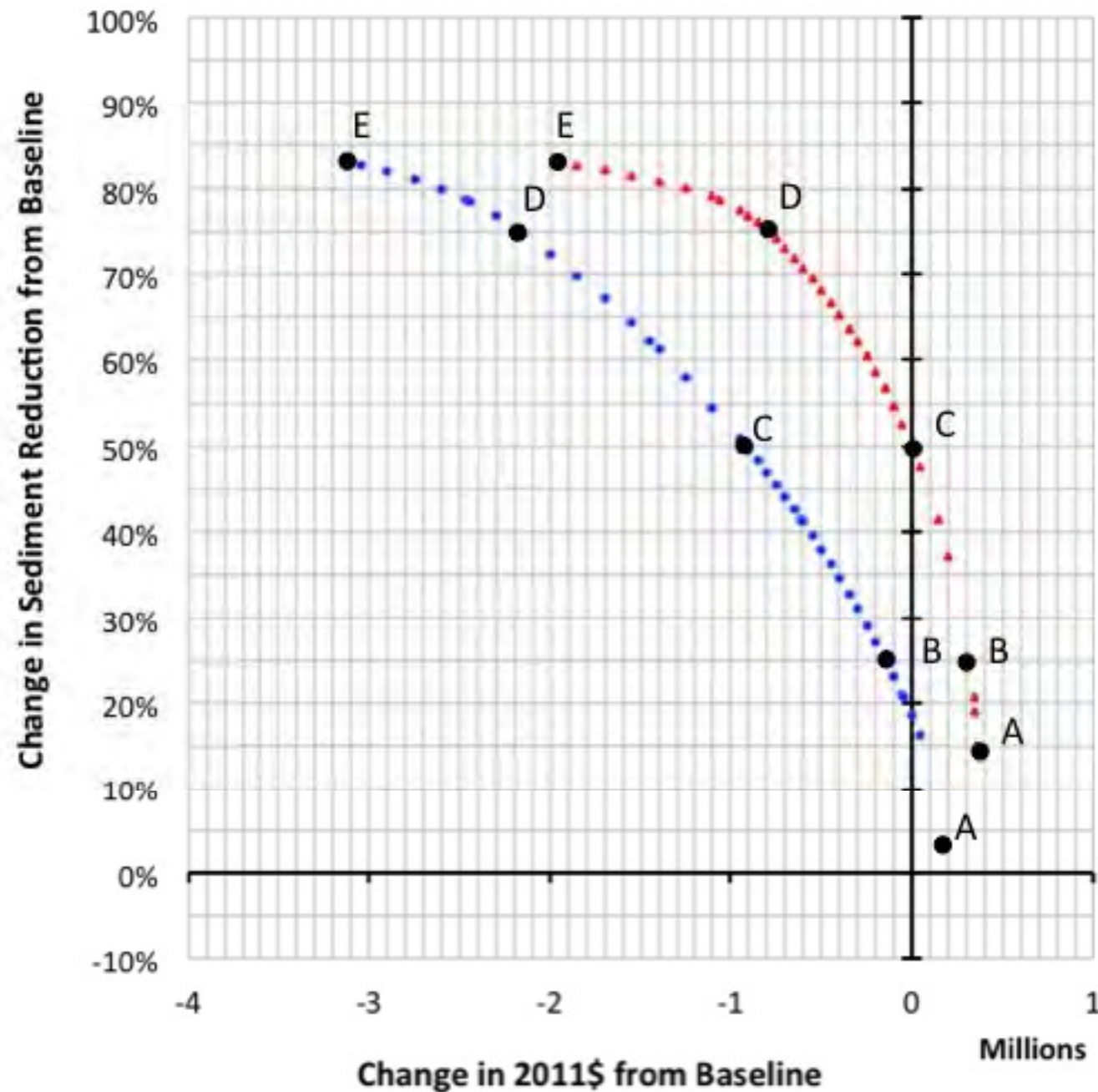


Water Budget - Switchgrass



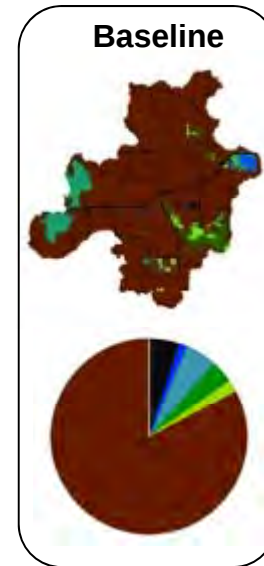
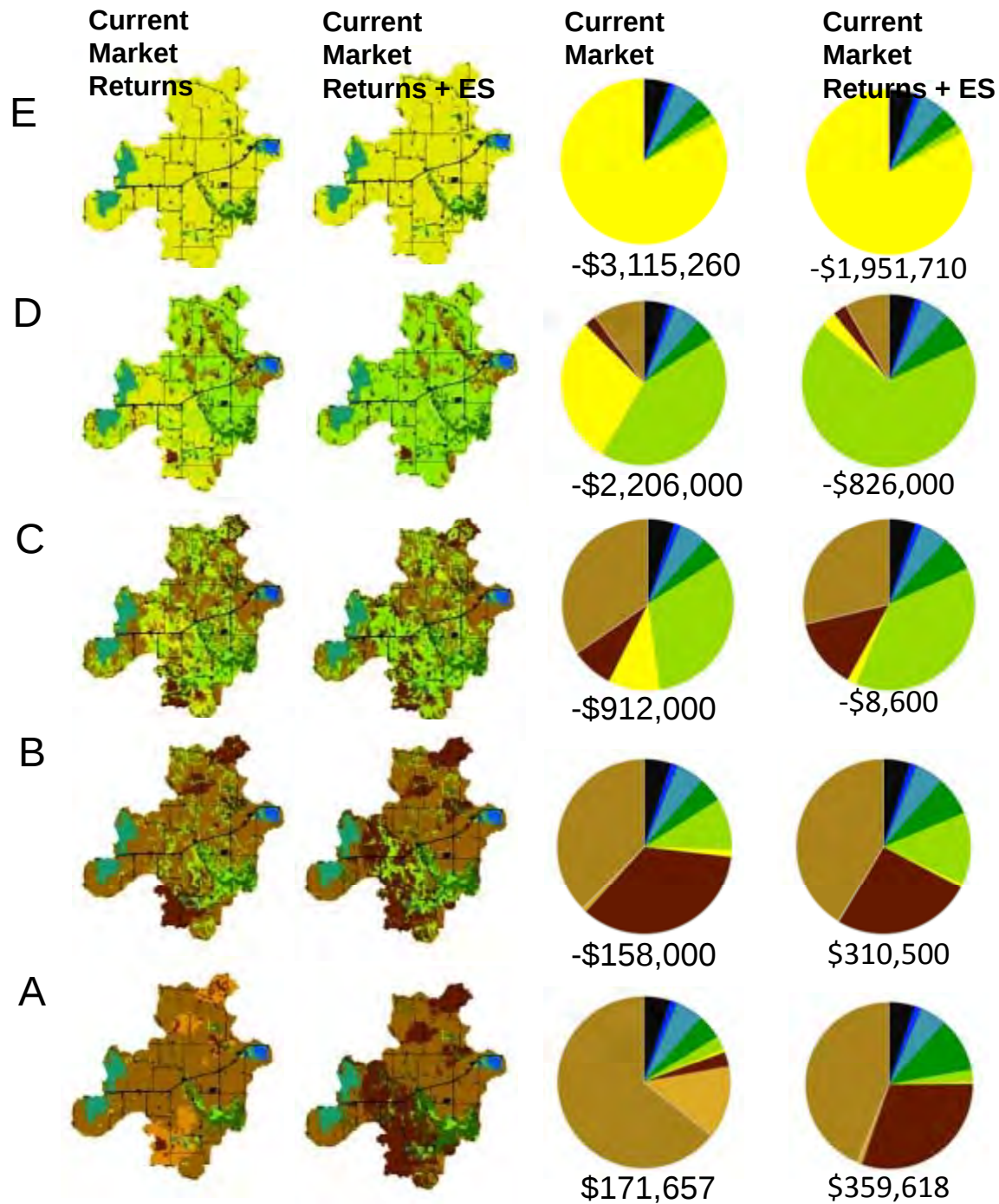


Efficiency frontiers for Sed reduction constrained by market returns and by total value



Adding non-market ecosystem service value:

- carbon sequestration
- Sediment reduction
- Phosphorus reduction

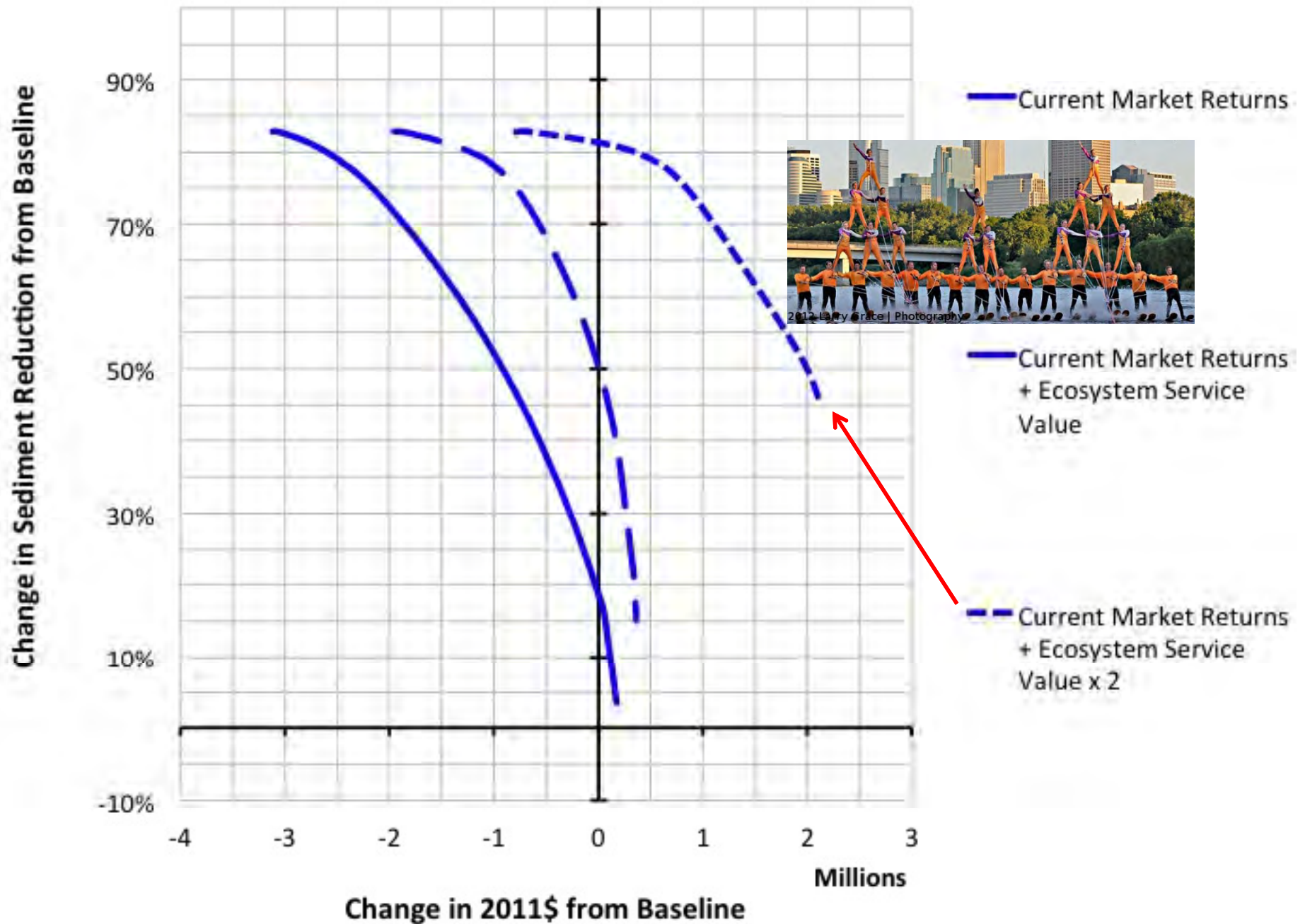


Additional content in final report:

Includes multiple landscape images (and valuation) for different points along various frontiers.

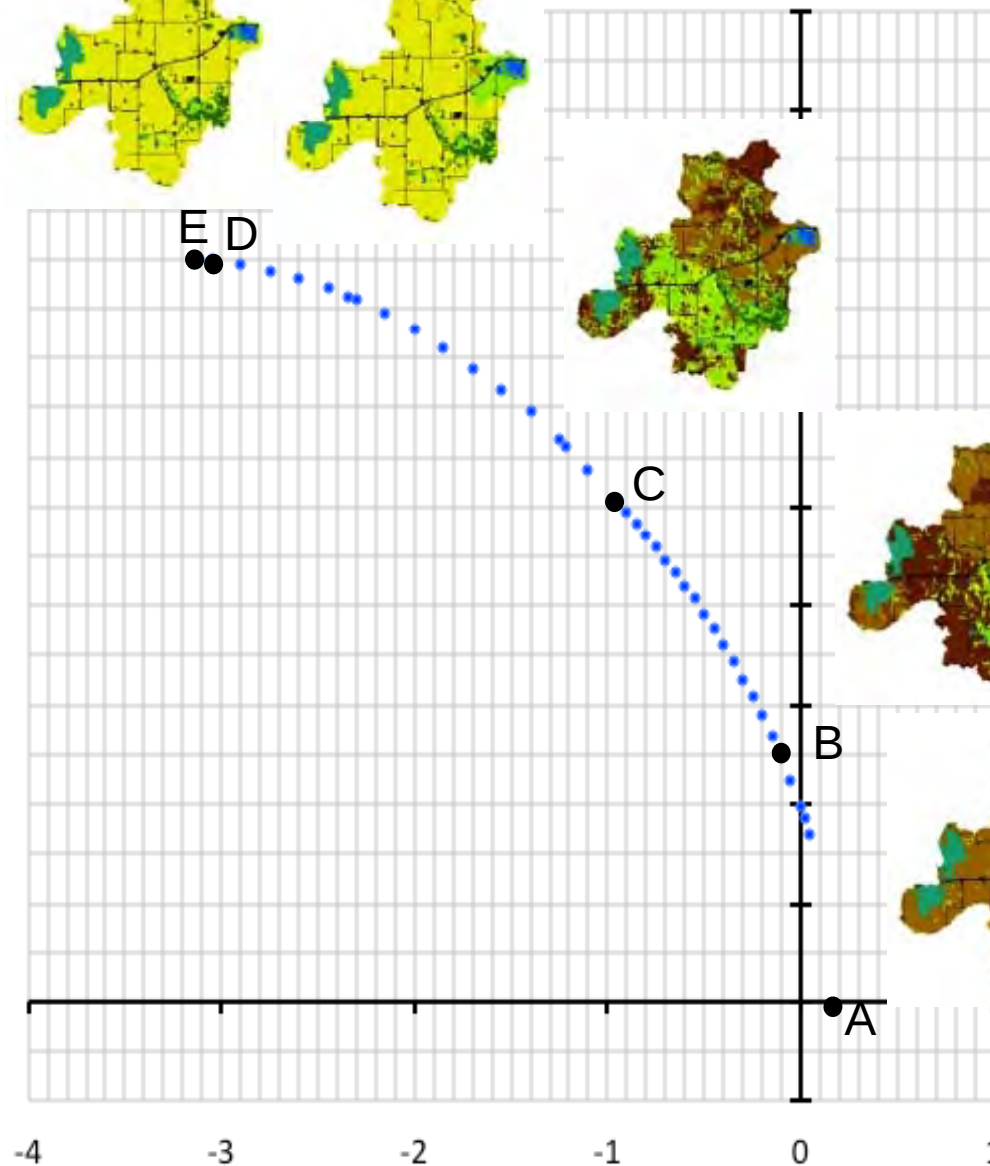


Efficiency frontiers for Sed reduction constrained by market returns and by total value



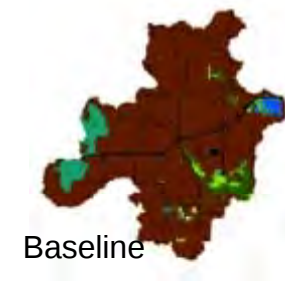
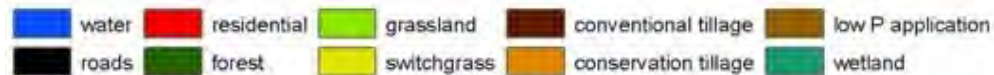
Change in Phosphorus Reduction from Baseline

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%



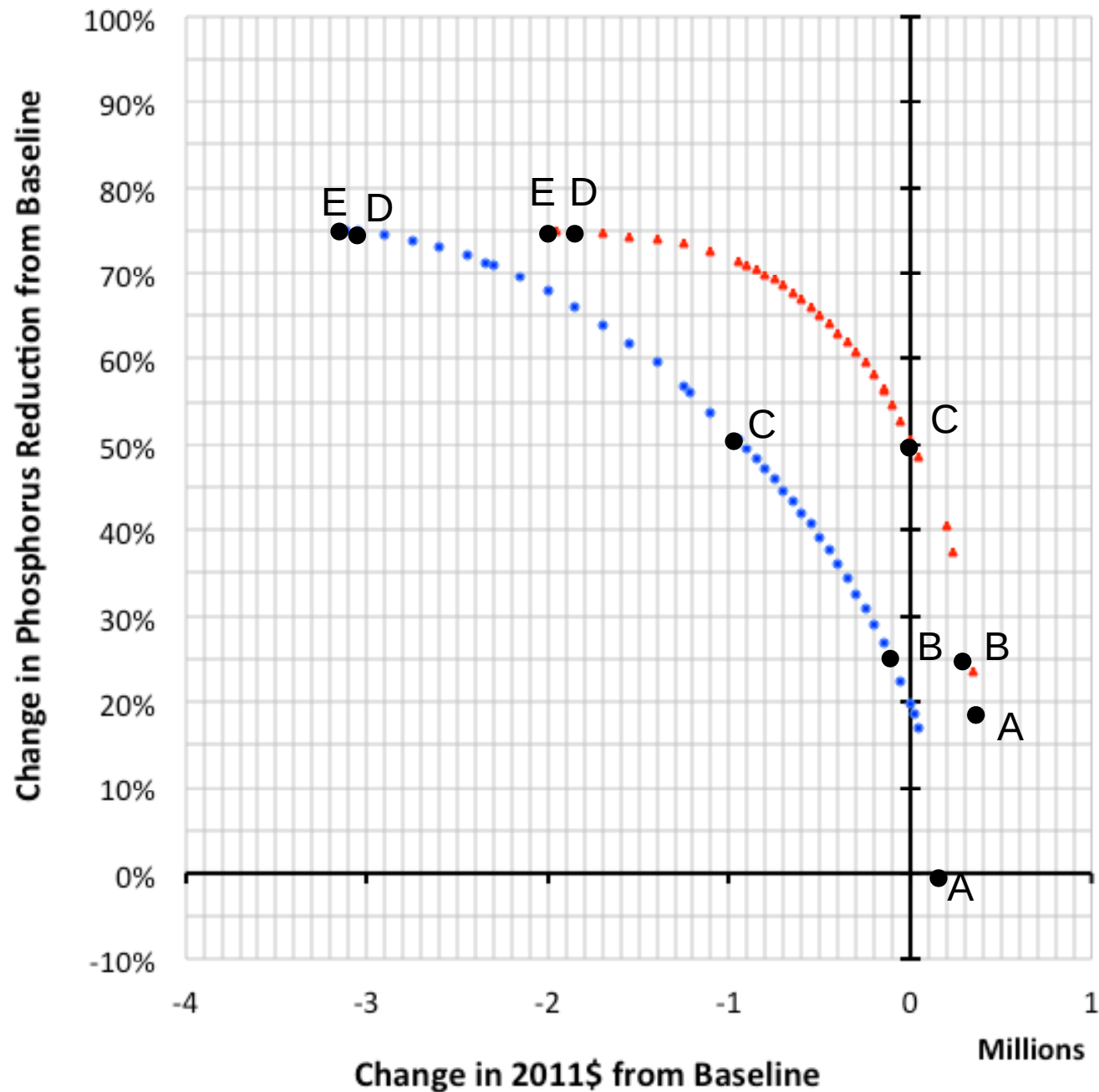
Change in 2011\$ from Baseline

Millions



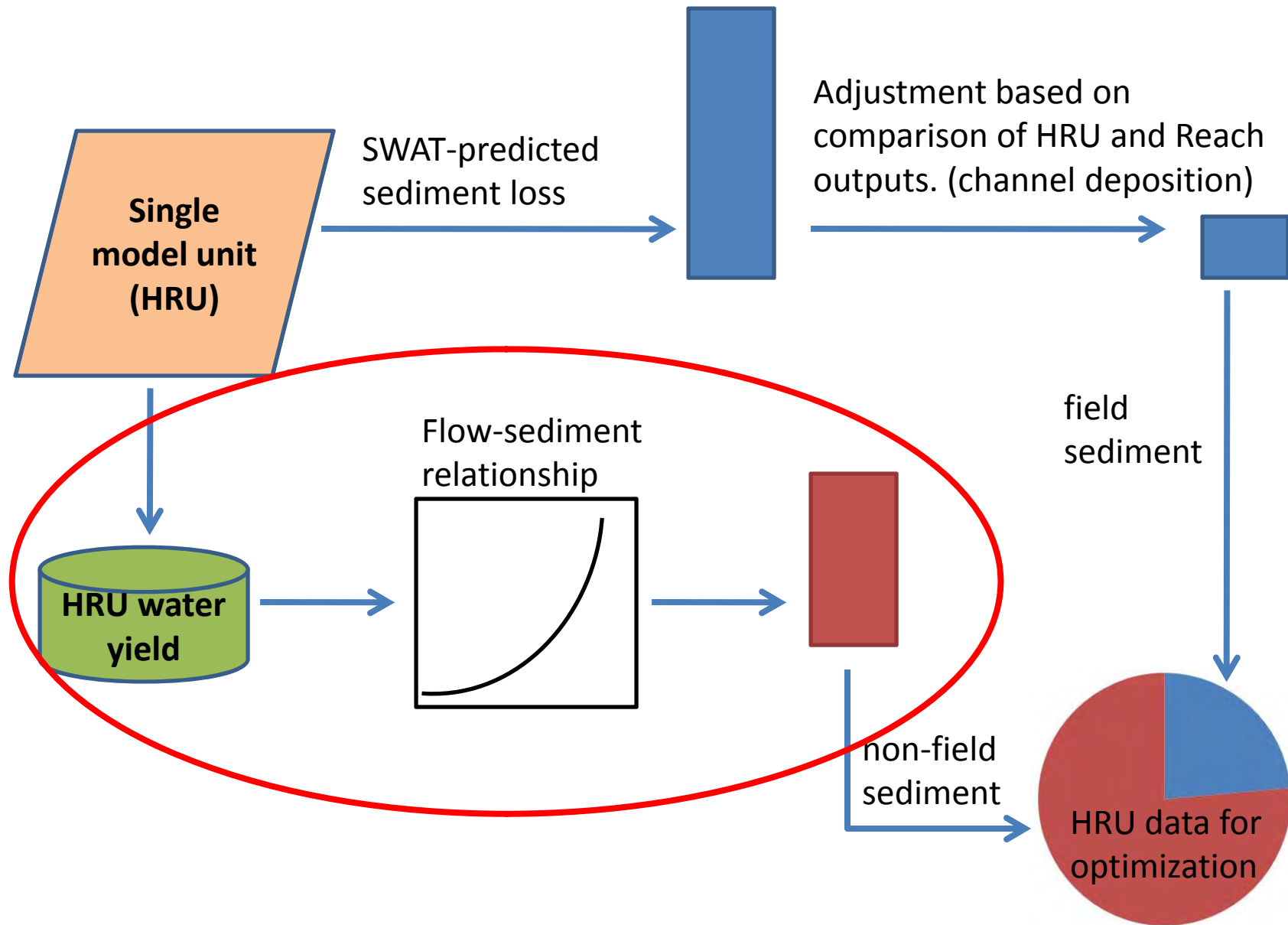
Seven Mile
Creek -
Phosphorus

Efficiency frontiers for P reduction constrained by market returns and by total value



What's the benefit of considering non-market ecosystem service value?

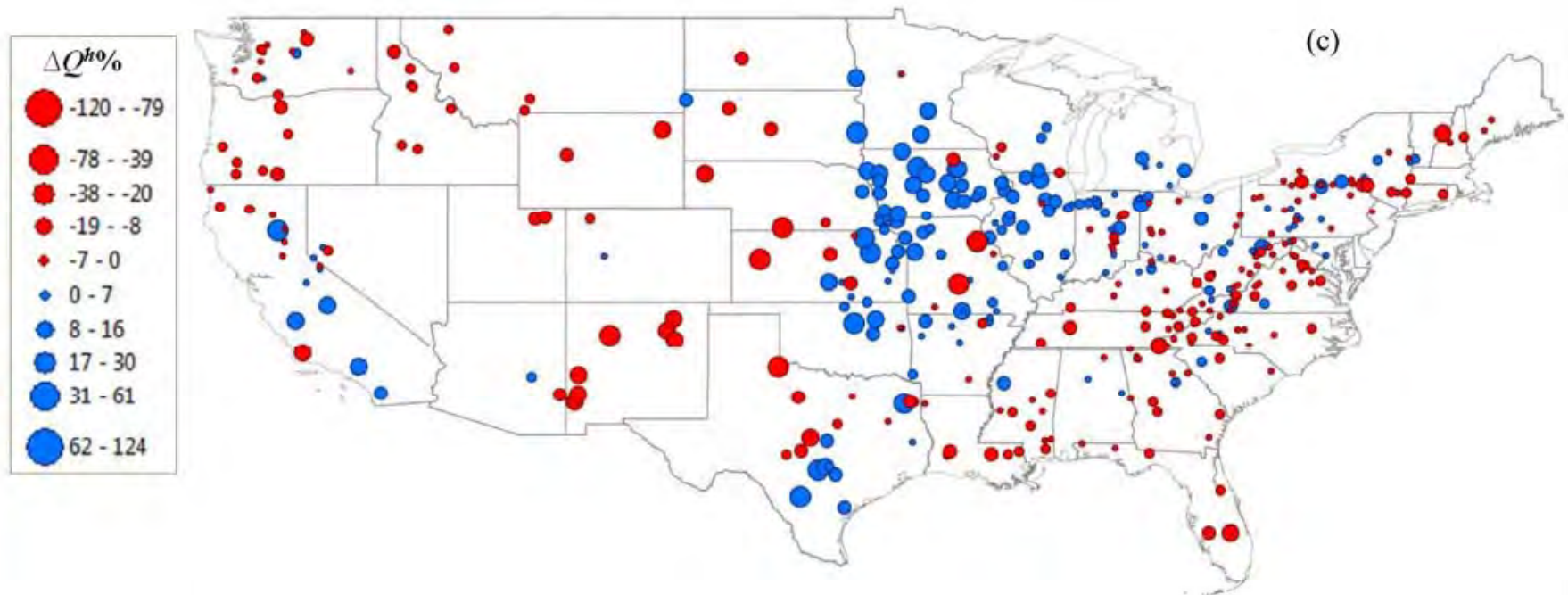
Data preparation schematic for optimization input



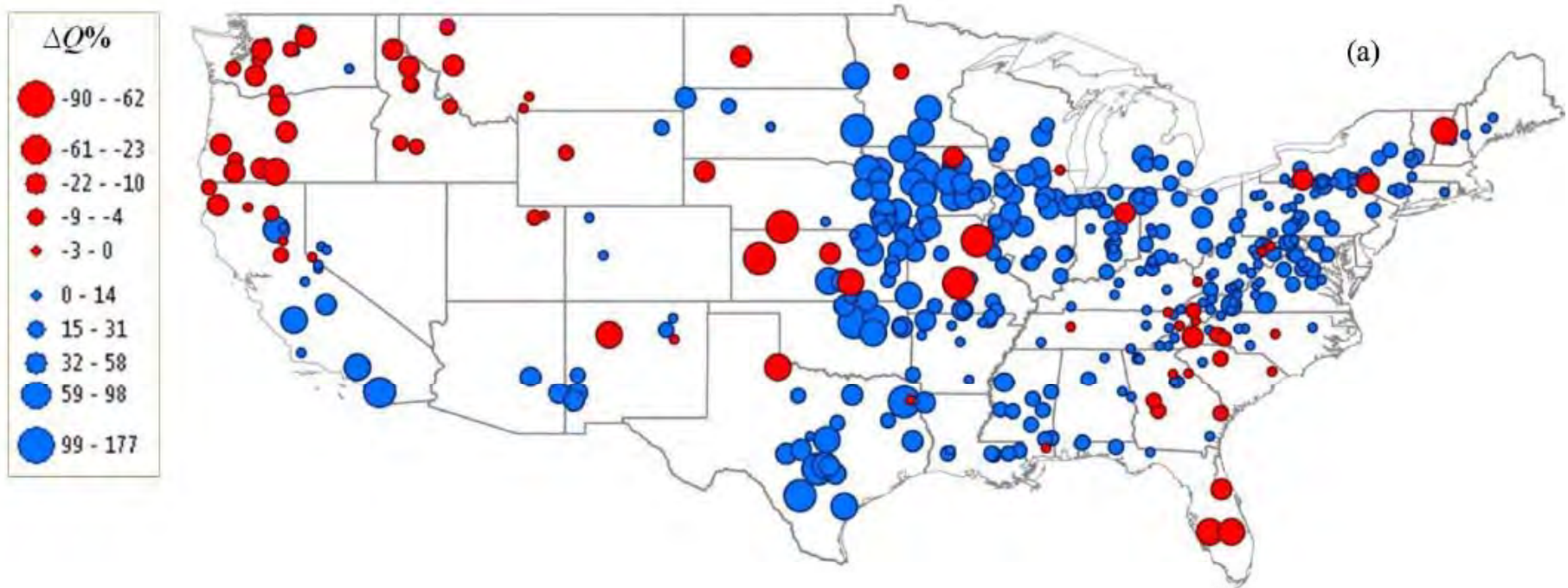
Changes in streamflow - climate



Changes in streamflow - humans



Changes in streamflow - total



Conclusions

- Modest gains in water quality are possible without reducing current economic returns (but standard best management practices will not achieve TMDL goals)
- 50% reductions are possible, but at substantial cost in terms of reduced economic returns

Conclusions

- The failure to incorporate the value of ecosystem services in land use planning can result in poor outcomes
 - Low level of ecosystem services
 - Low value of total goods and services from landscape
- Important to include value of ecosystem services in land use planning and incentives to landowners

Thank you!

