Application of a coupled SWAT-BATHTUB model to evaluate phosphorus critical source areas and land management alternatives on the water quality of Lake Prespa, Macedonia

Presented at the 2015 international SWAT conference, Sardinia, Italy

24 June 2015

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Presentation Outline

Study area

Study objectives

SWAT model:
- Development
- Calibration and Validation

BATHTUB model
- Background and development
- Simulation results

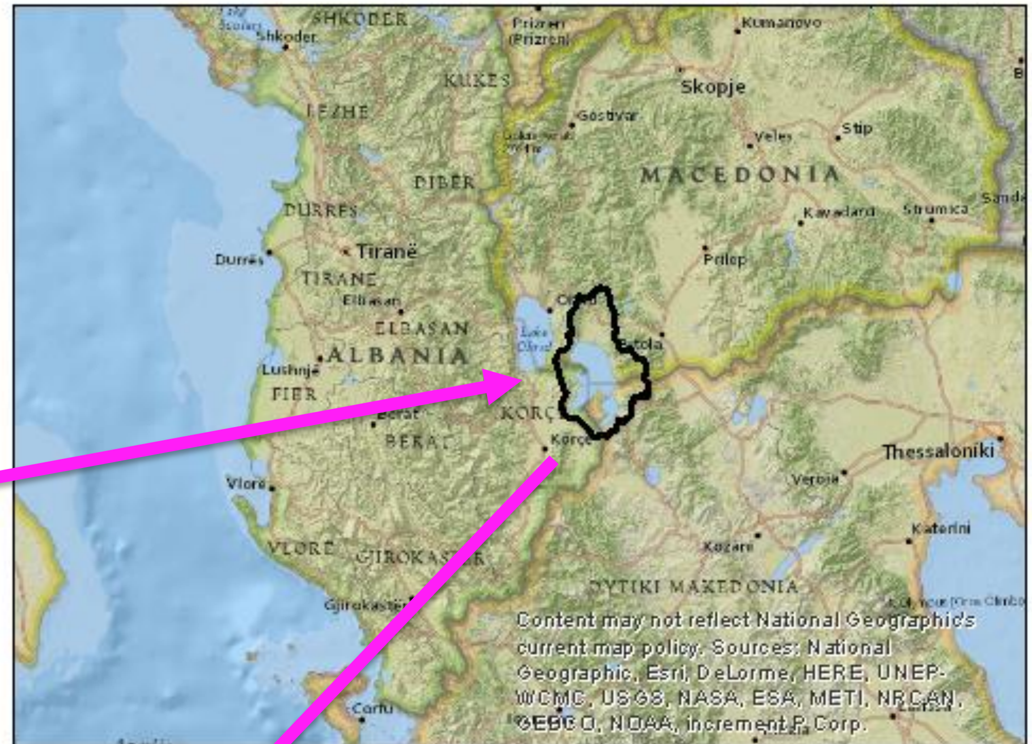
Phosphorus critical source area (CSA) analysis

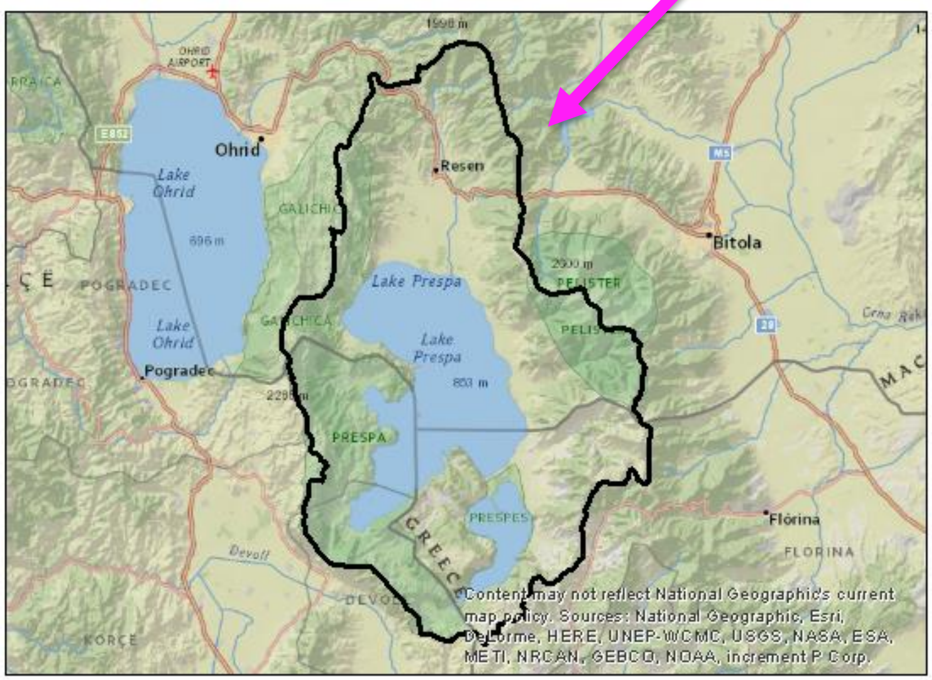
Alternative management practices (preliminary results)

Conclusions and next steps

Study Area: Lake Prespa

You are here!





International:
- Macedonia
- Albania
- Greece

Watershed area:
- Land: 1,054 km^2
- Lake: 305 km^2

Elevation:
- Min: 823 m
- Max: 2,420 m

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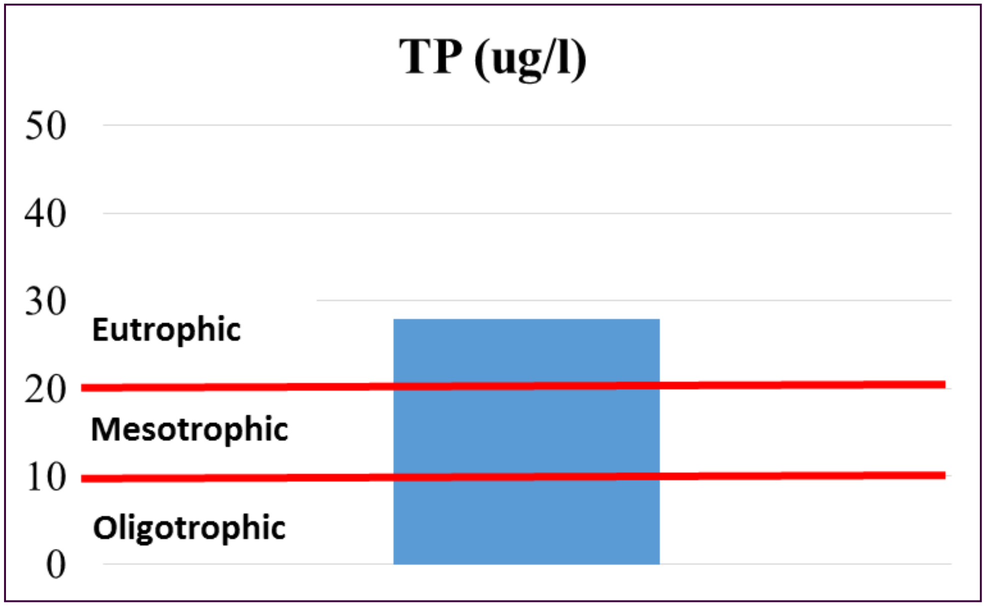
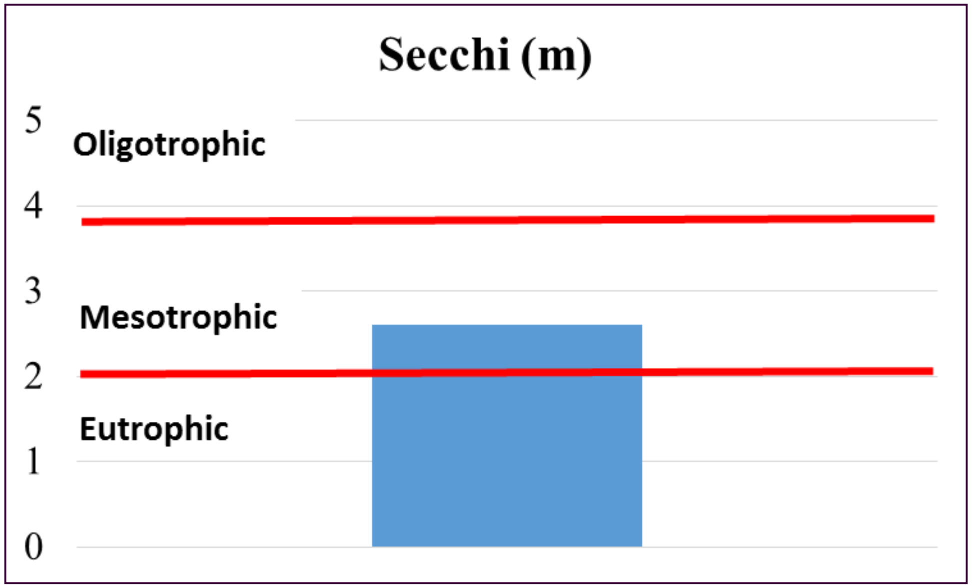
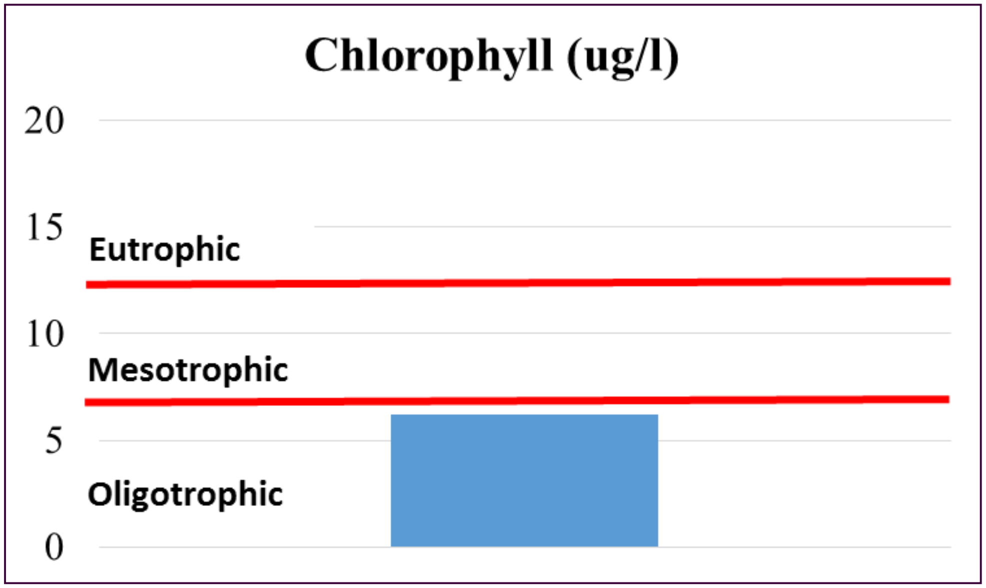
Study Area: Lake Water Quality Status

Based on 2014 monitoring data, Prespa lake can be classified as:

- *eutrophic* based on TP
- *mesotrophic* based on secchi depth and Chl-A concentrations







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Study Objectives

Develop a coupled SWAT/BATHTUB model

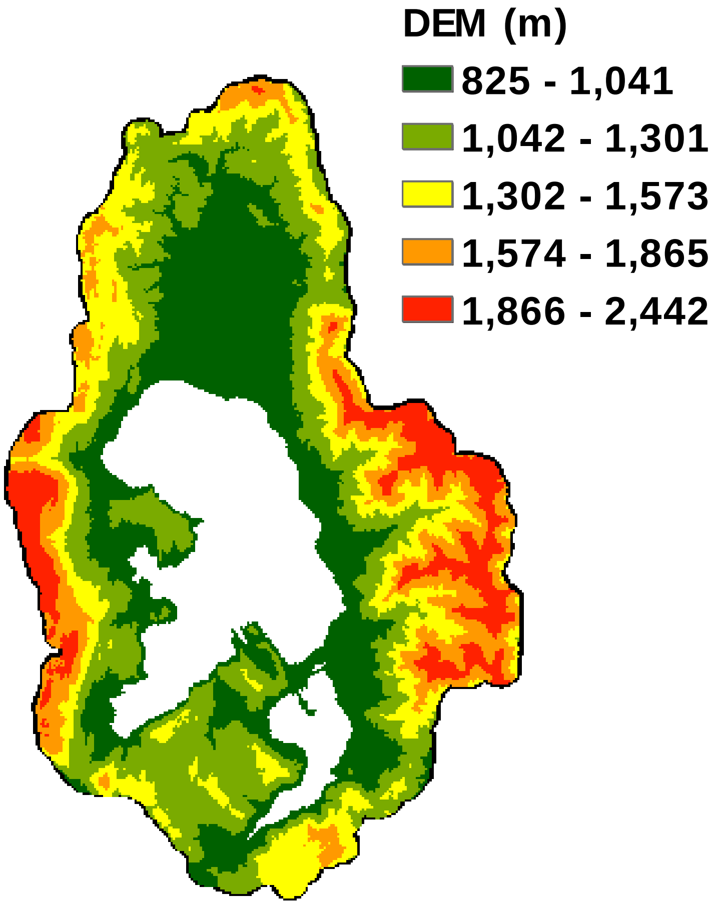
Identify phosphorus CSAs

Develop and evaluate alternative management practices

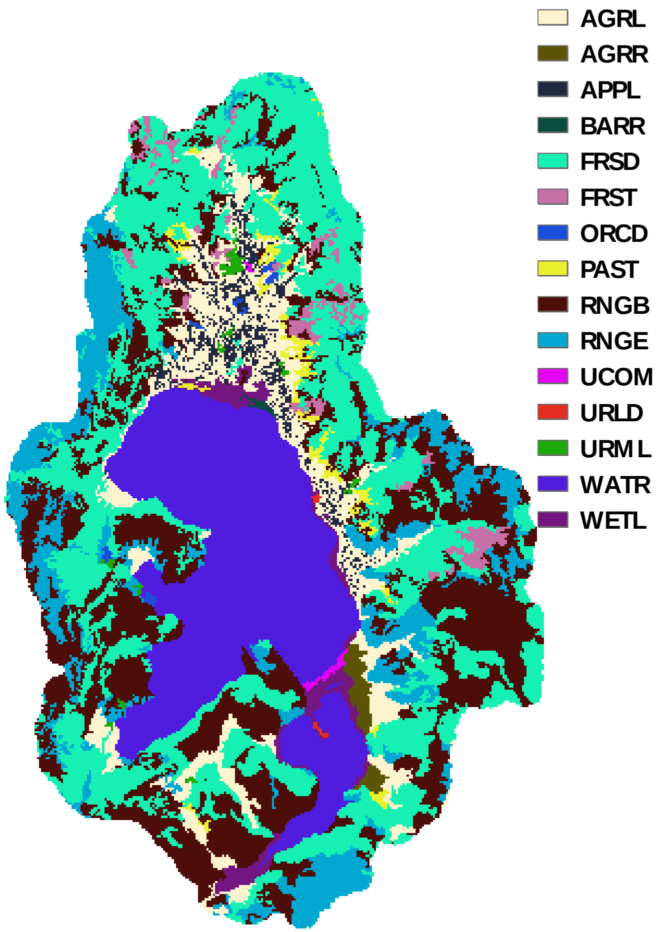
Determine impact of alternatives on lake water quality

Compile knowledge gained into a management tool for UNDP to guide future activities in the watershed

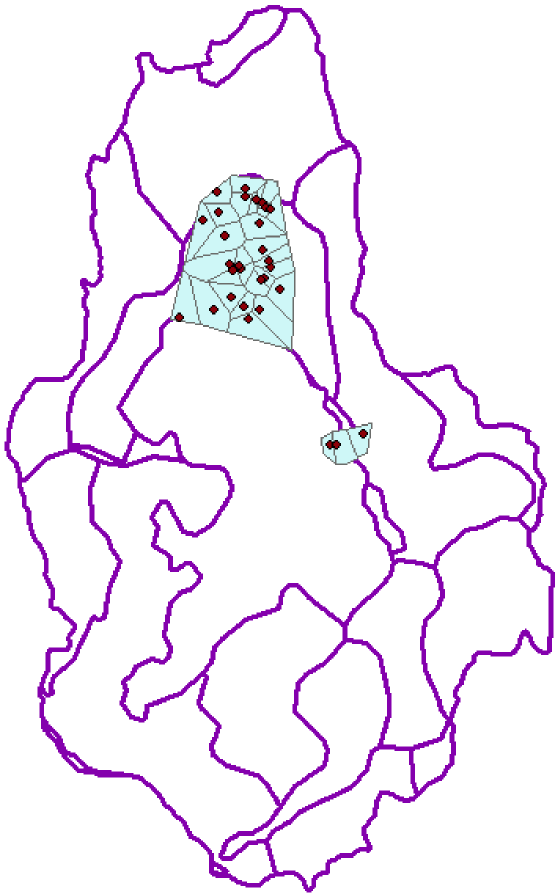
SWAT Development: Subbasin/HRU Delineation Data



UNDP (20 m) and ASTER (30 m) stitched to produce 20 m DEM



CORINE 2000/2006 (100 m) and vector orchard boundaries stitched and resampled to produce 20 m land use



ESDB (1 km), FAO (10 km) and 32 UNDP field samples integrated to produce soils data

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SWAT Development: Subbasin/HRU Delineation Results

Land Use:

- 80% undeveloped
- 19% agriculture
- 1% developed

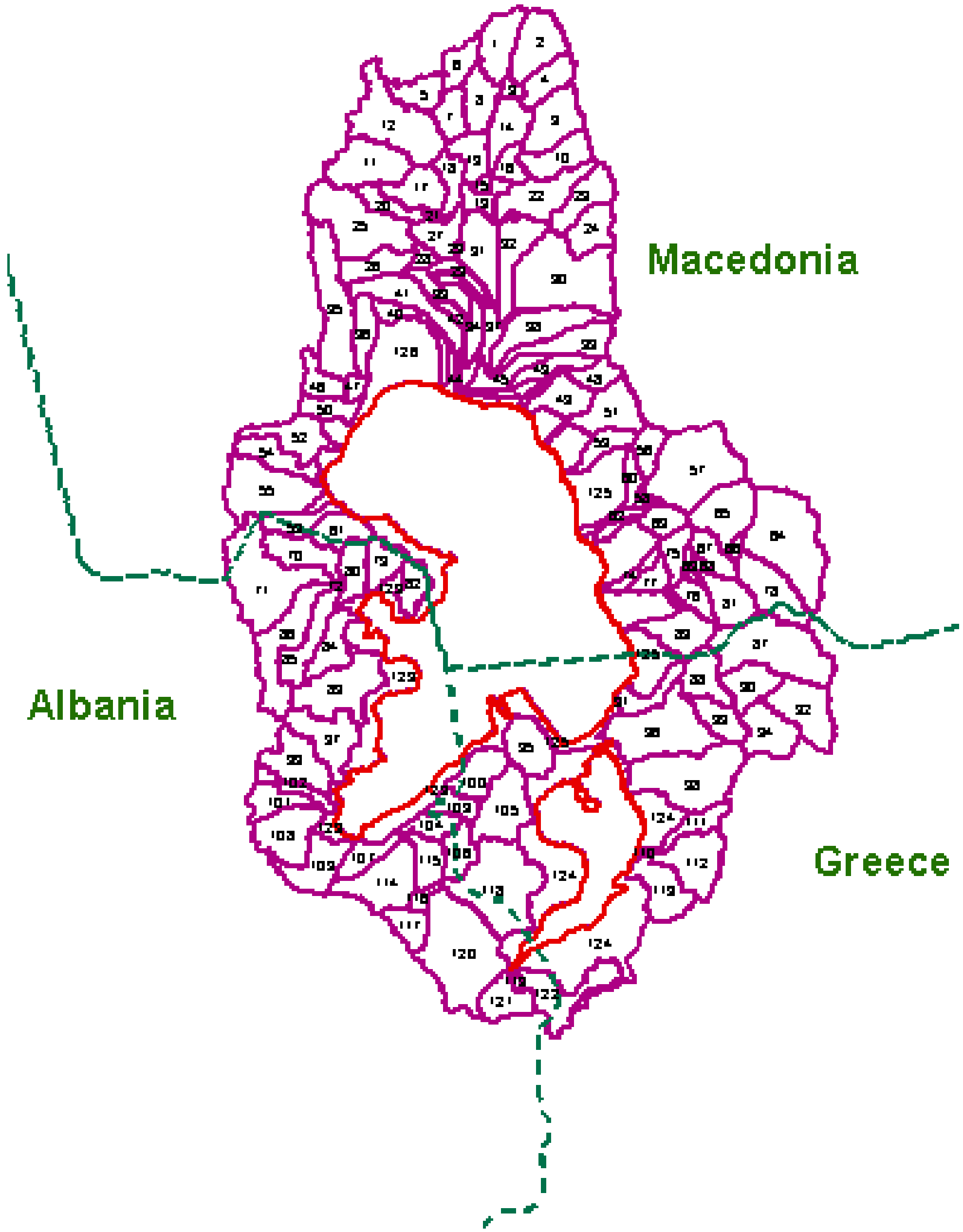
Soils: 48 soils classes, hydro group C dominant

Slope: 5 classes

- 0 – 3%: 10%
- 3 – 15%: 21%
- 15 – 25%: 17%
- 25 – 50%: 38%
- > 50%: 13%

HRU Delineation: No thresholds applied

- 126 subbasins
- 5,061 HRUs total



SWAT Model Development: Weather and Agronomy

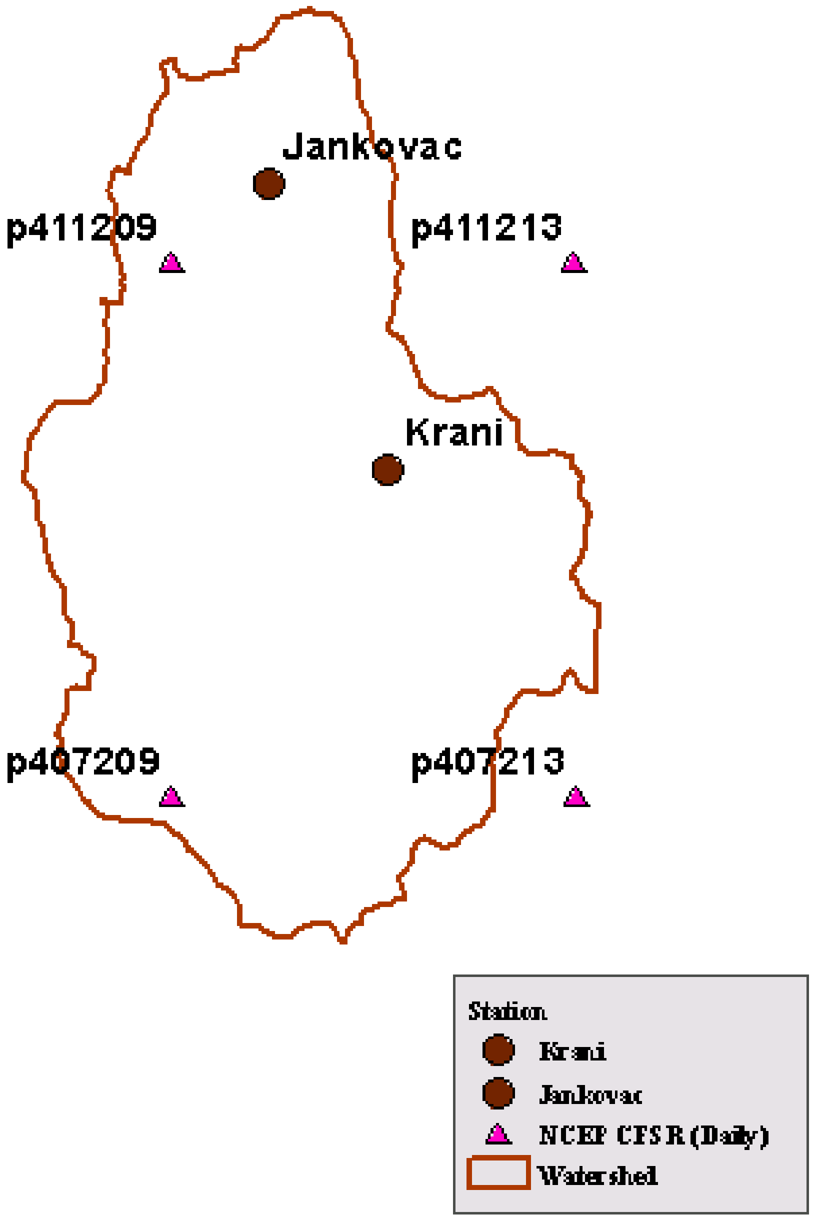
Daily precipitation and temperature :

- NCEP CFSR, 1979-2013, 4 stations
- UNDP 2006-2014, 2 stations

Lapse rates generated from long term isohyetal and temperature maps

Agronomic management schedules:

- Apples, wheat, potato (Macedonia)
- Corn, lima bean (Greece, Albania)
- Timing and frequency of planting, harvesting, tillage, irrigation, and fertilizer applications derived by local agronomist.



SWAT Calibration: Streamflow data

Monthly streamflow: 1983 – 2010

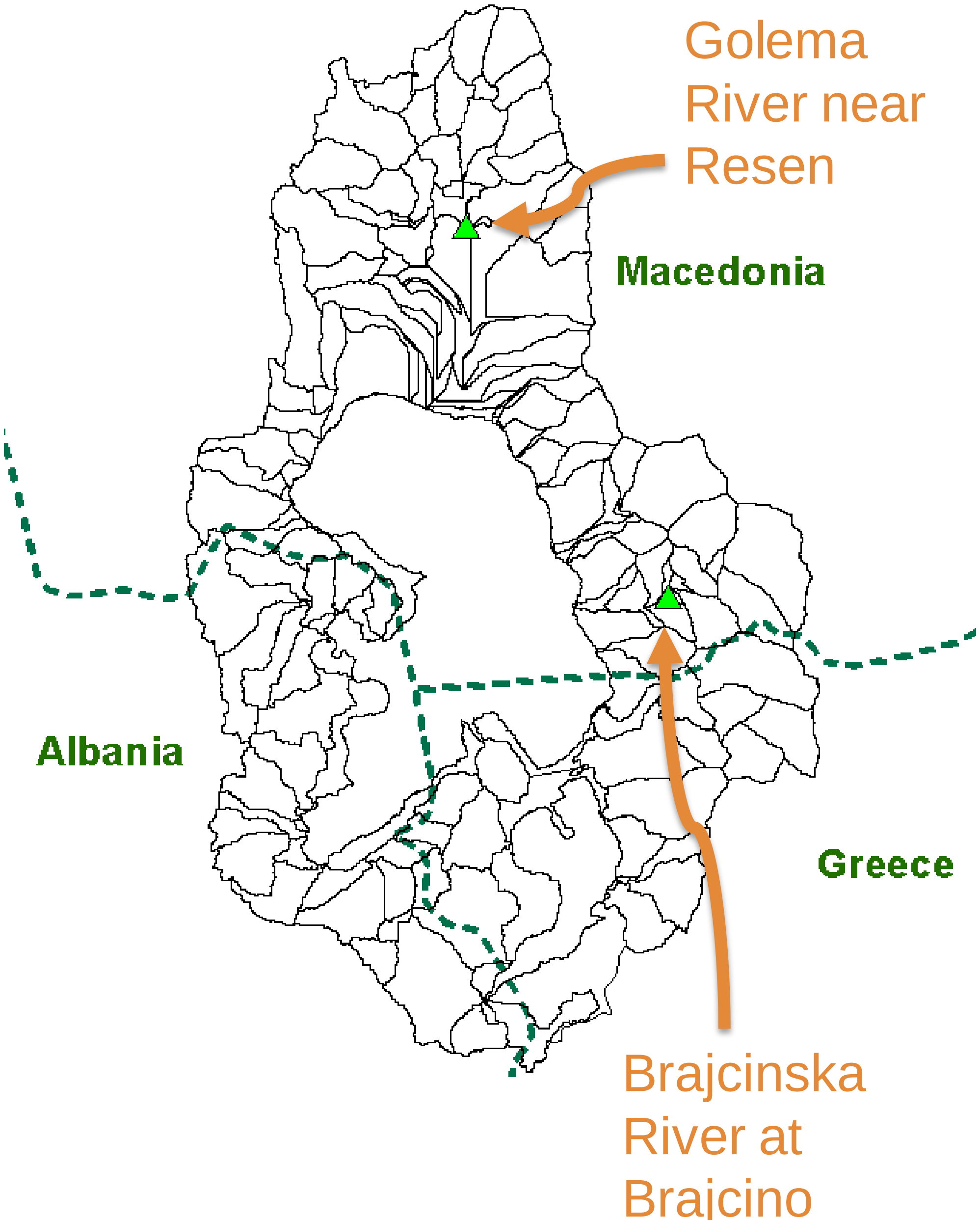
- Brajcinska River at Brajcino
- Golema River near Resen (estimated)

Model warmup: 1979-1982

Calibration: 1997-2010

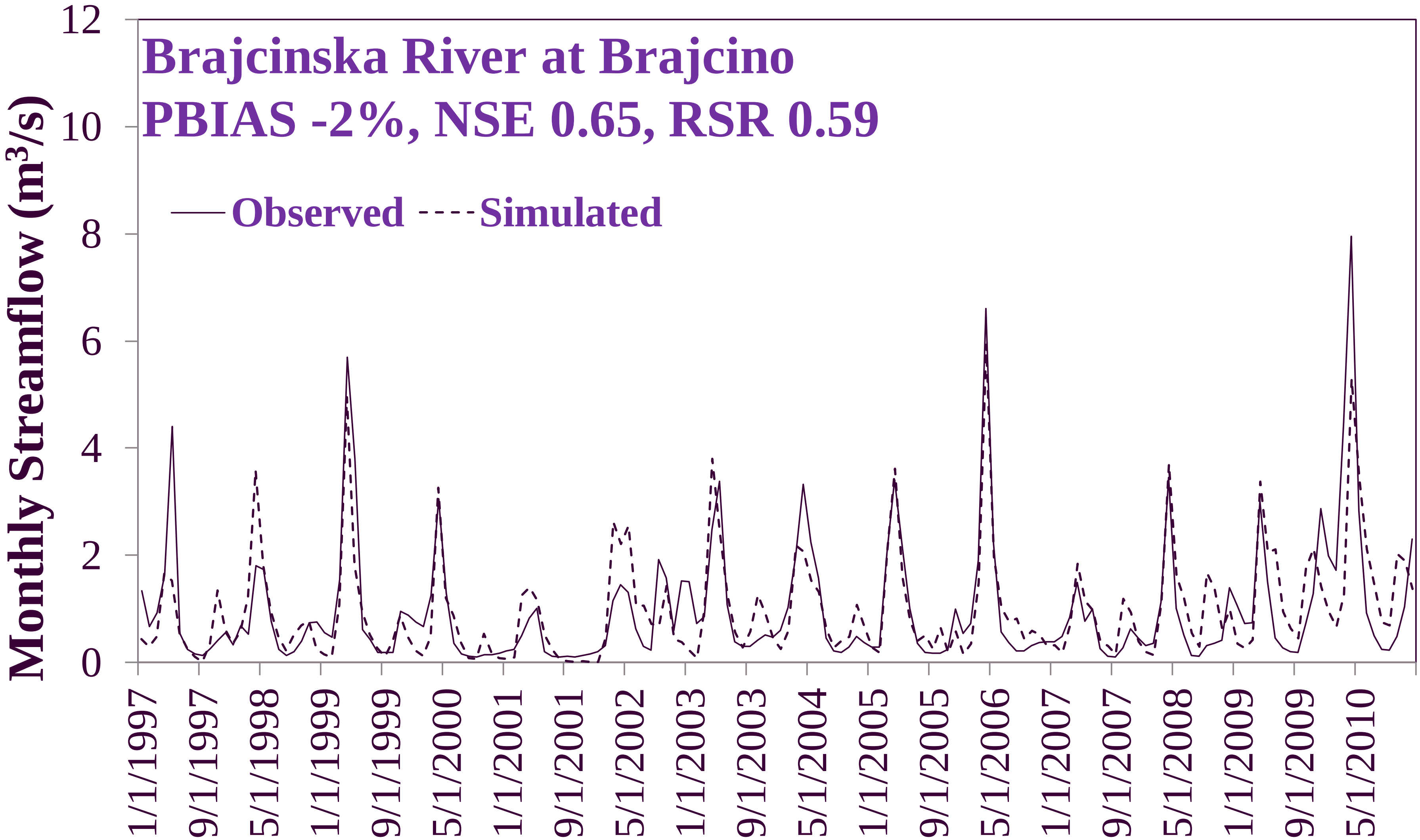
Validation: 1983 – 1996

Model performance evaluated based on guidelines by Moriasi et al. (2007)



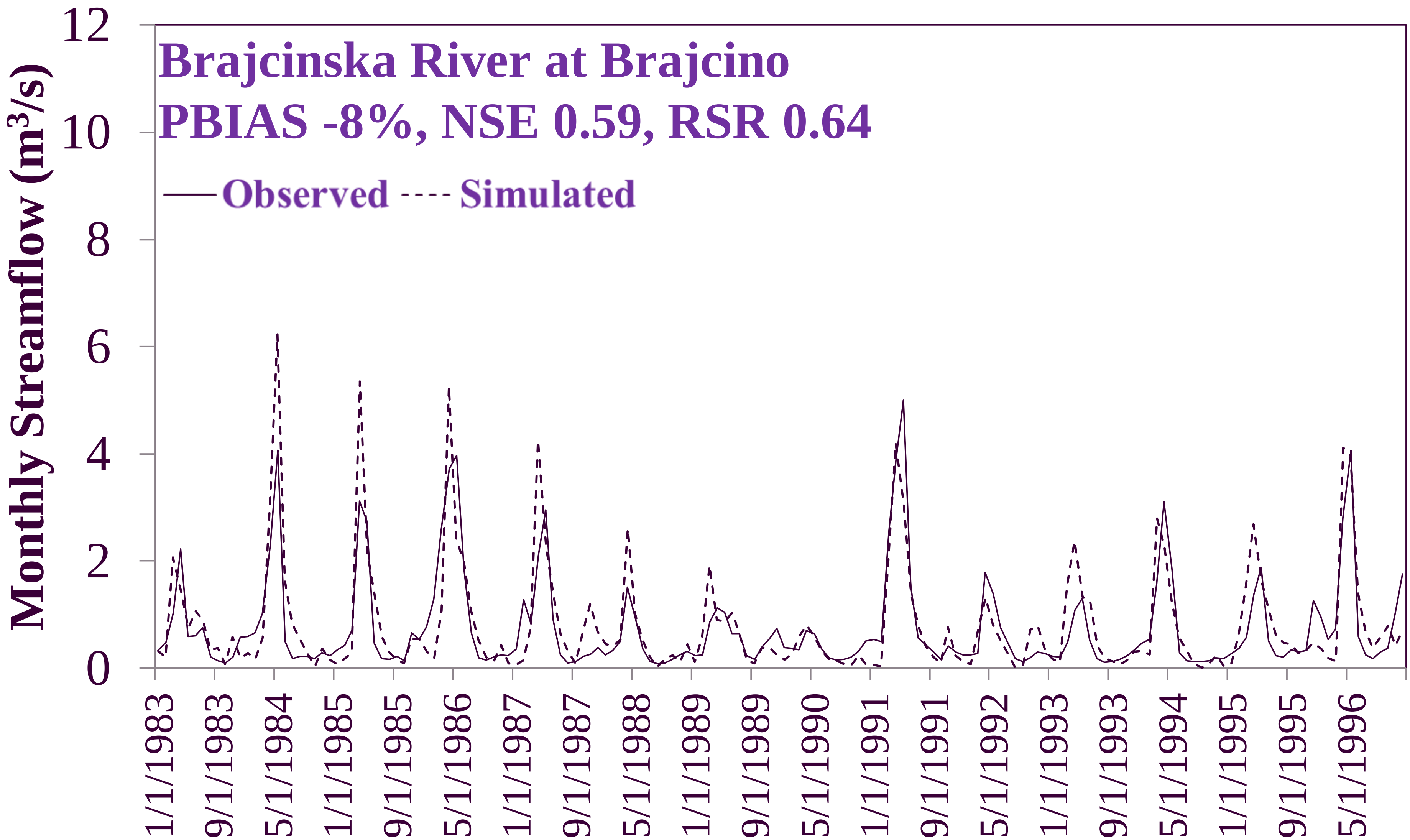
Moriasi, D. N., J. G. Arnold, M. W. Van Liew, R. L. Bingner, R. D. Harmel and T. L. Veith. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Trans. ASABE 50(3):885-900.

SWAT Calibration: Example Streamflow Results



Based on performance evaluation criteria, PBIAS is "very good", NSE is "satisfactory", and RSR is "good"

SWAT Validation: Example Streamflow Results



Based on performance evaluation criteria, PBIAS is “very good”, NSE and RSR are “satisfactory”

SWAT Calibration: Water Quality Data

Monitoring data: 8 sites, 12/2013-12/2014 (continuing in 2015)

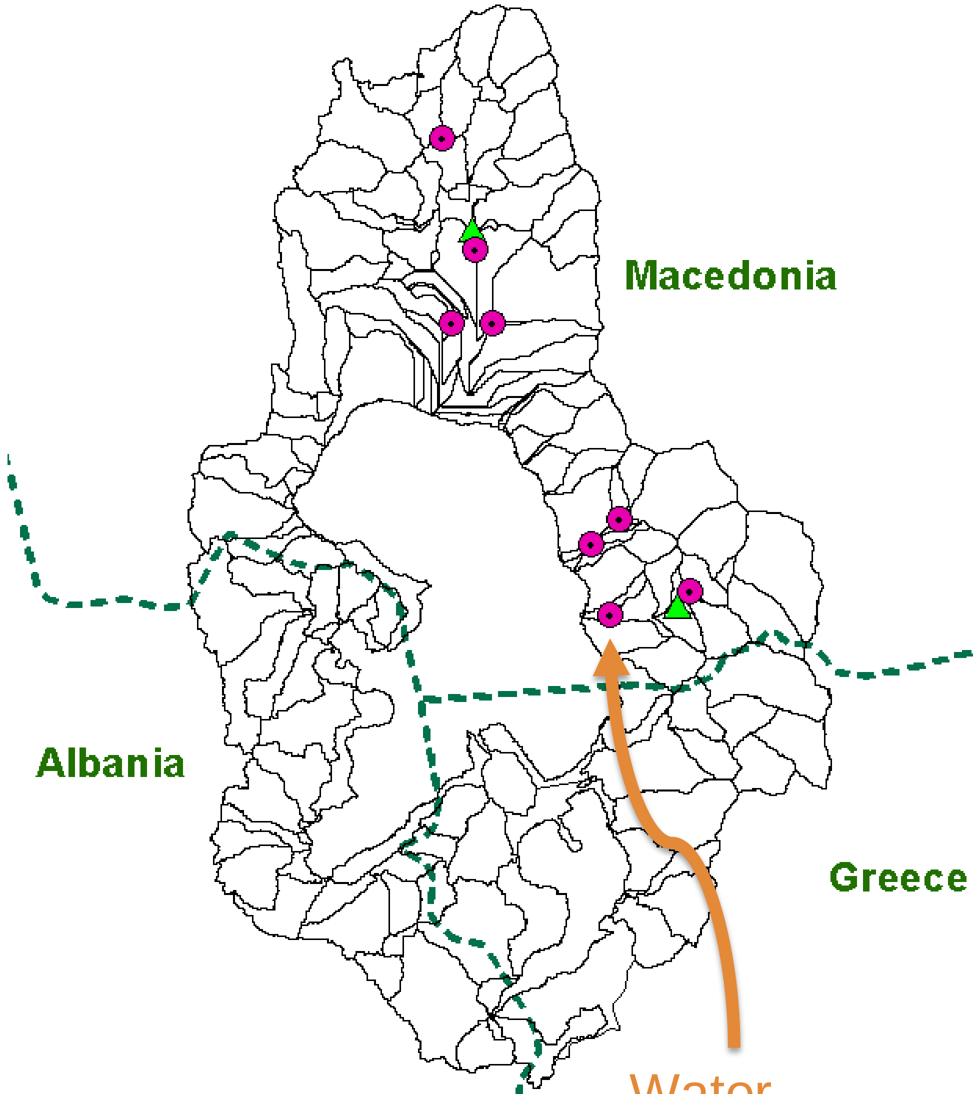
Between 6 and 11 samples per site

Majority of samples during low flows

Calibration Strategy:

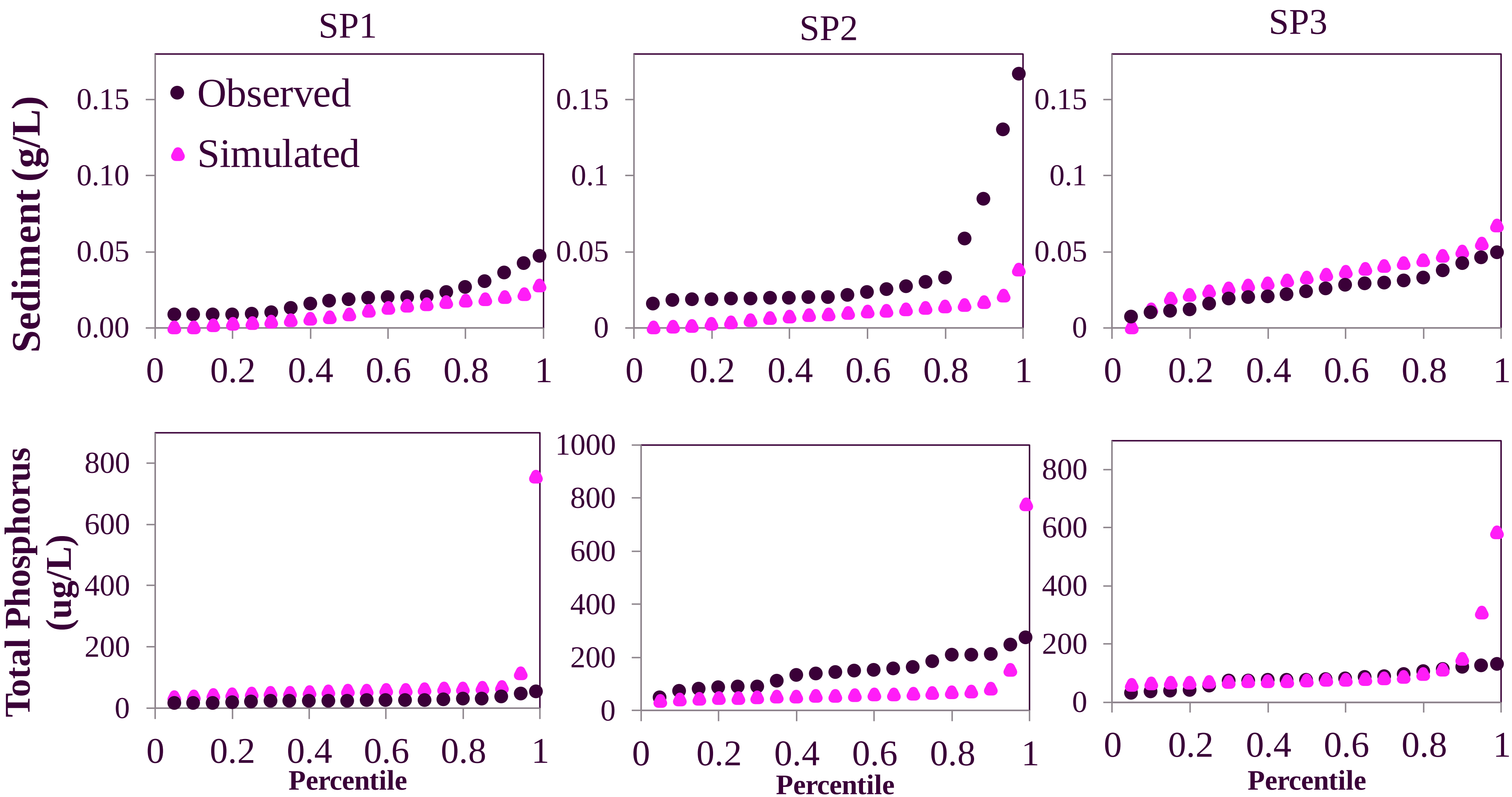
- Qualitative comparison of observed concentration distributions with simulated distributions (same flow rate range)

- Watershed-level calibration, uniform parameter adjustments



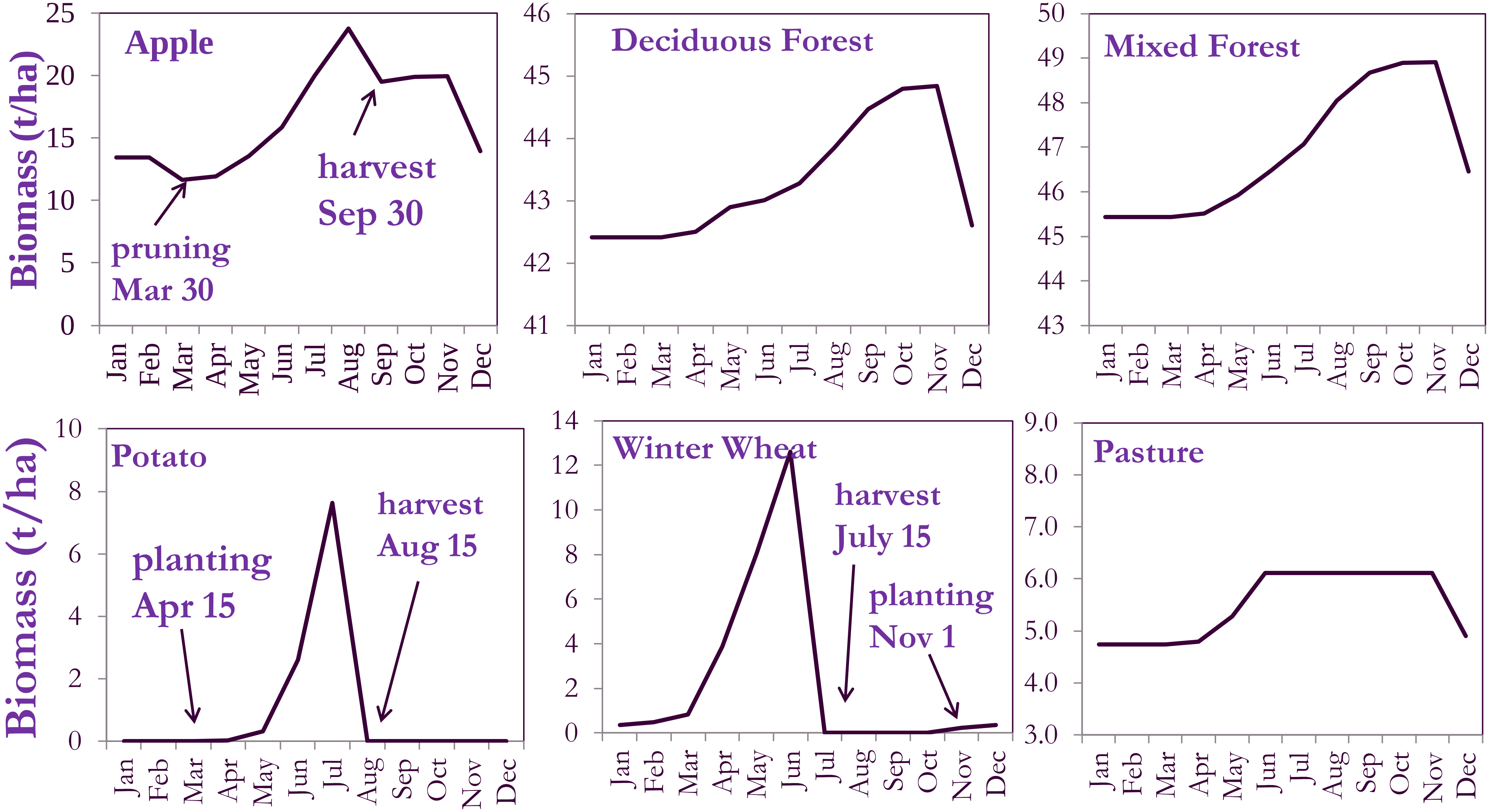
Water quality stations

SWAT Model Calibration: Example Water Quality Results, 3 of 8 Sites



Sediment and TP simulations very close to observed data. Over predictions in the highest percentiles likely reflect lack of monitoring data during high flows

SWAT Model Calibration: Landscape Analysis, Plant Growth



Seasonal biomass growth pattern considered reasonable by a local agronomist

SWAT Model Calibration: Landscape Analysis, Total P by Soil Hydrologic Group

	Soil Hydrologic Group			
	A	B	C	D
Apple	1.24	1.33	1.53	1.48
Barren	0.34	NA	NA	NA
Urban	0.13	0.15	0.28	0.57
Corn	NA	NA	10.31	NA
Forest Deciduous	0.09	0.09	0.11	0.06
Forest Generic	0.09	0.09	0.13	NA
Lima	NA	NA	8.21	NA
Pasture	0.09	0.10	0.13	0.06
Potatoes	2.01	4.27	6.26	1.57
Range Brush	0.11	0.10	0.16	NA
Range Grass	0.11	0.12	0.18	NA
Wetlands	0.09	0.10	0.13	0.11
Winter Wheat	0.79	1.79	2.66	0.80

Forest and wetlands generate lowest total P

Loads from urban areas higher than undeveloped

Highest loads from heavily cultivated agriculture (corn, lima, potato)

P load generally increases from A to C soils

D soils, a very small fraction of the watershed (0.5%) did not follow expected trend.

SWAT-BATHTUB Coupling: BATHTUB Background

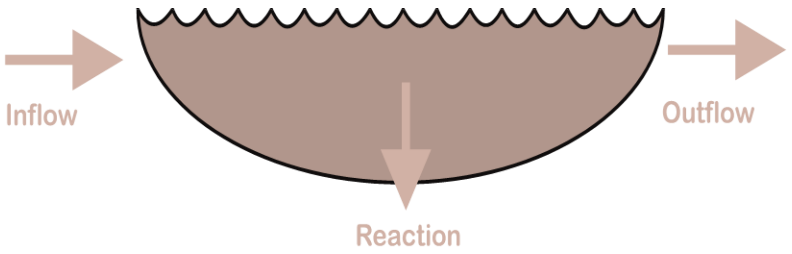
Steady-state model

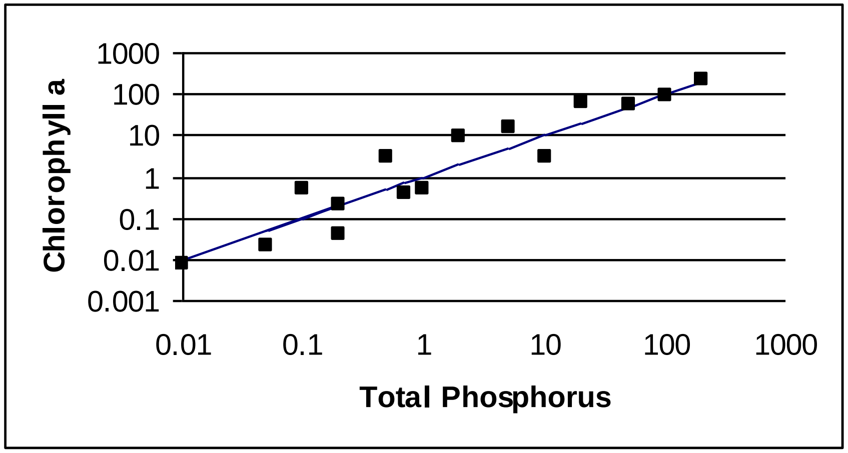
A combination of mechanistic and empirical sub-models

Empirical equations based on 2.5 million observations from 271 lakes

Model outputs include:

- Total phosphorus
- Total nitrogen
- Chl-A
- Transparency
- Hypolimnetic oxygen demand



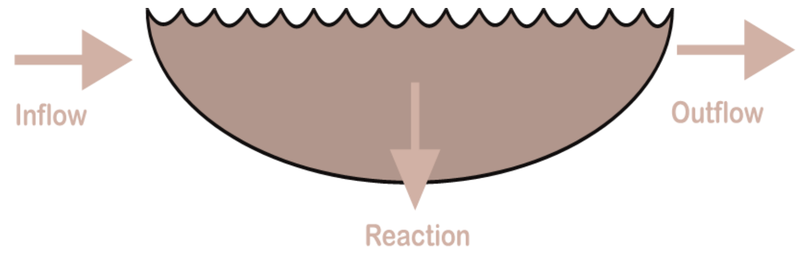


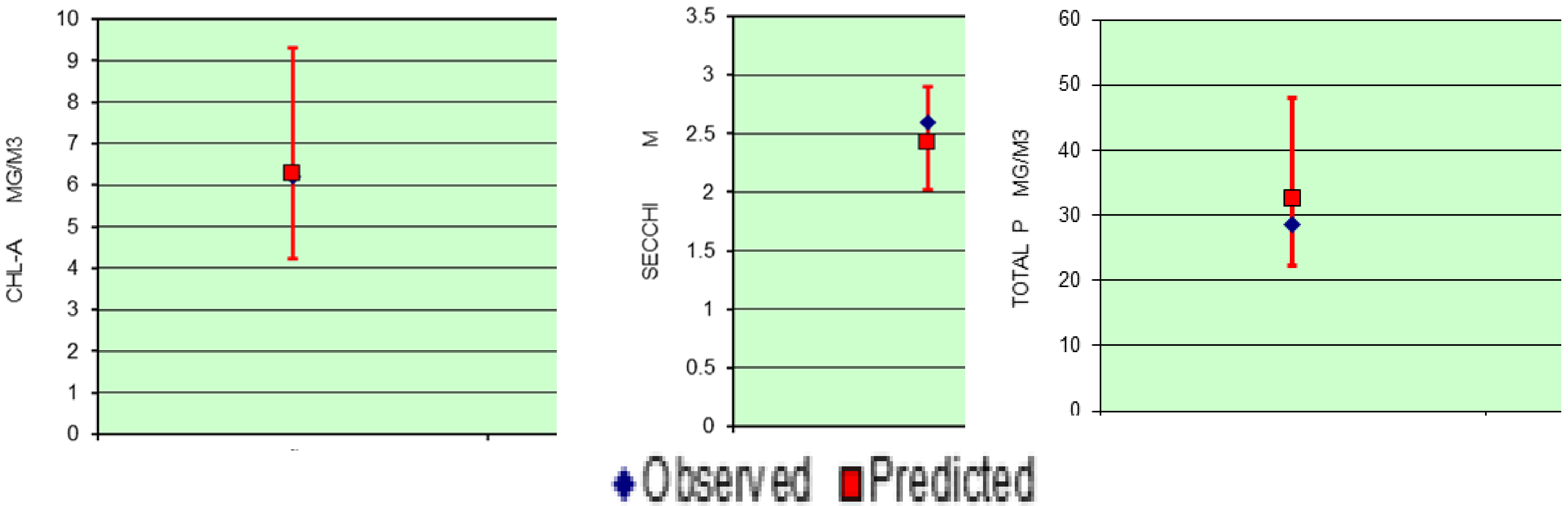
SWAT-BATHTUB Coupling: BATHTUB Results

BATHTUB simulation for Lake Prespa run with 2013 -2014 SWAT P load as input

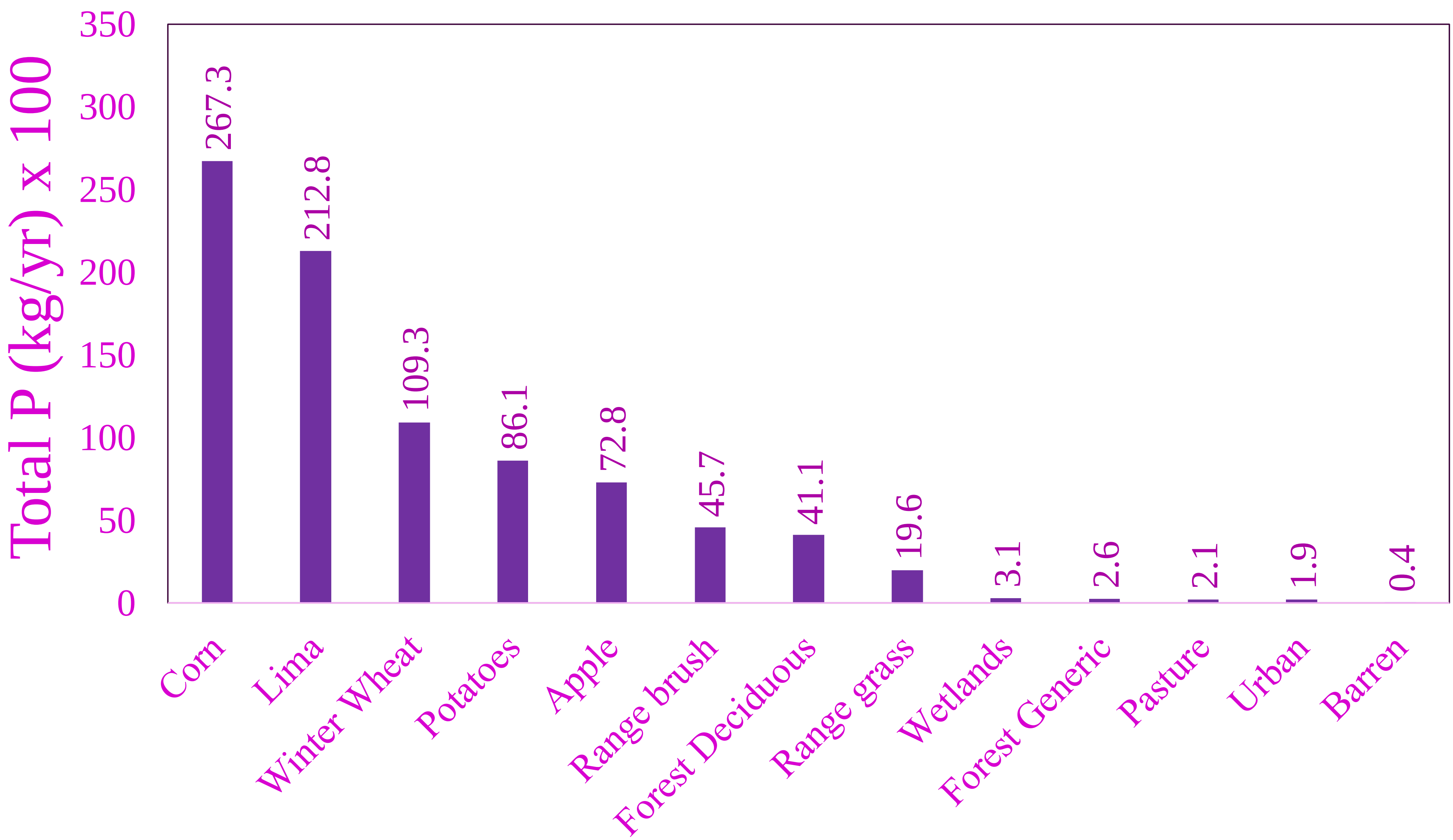
Model calibrated to 2014 monitoring data

Results showed Total P, Chl-A, and Secchi depth observations within range of simulation



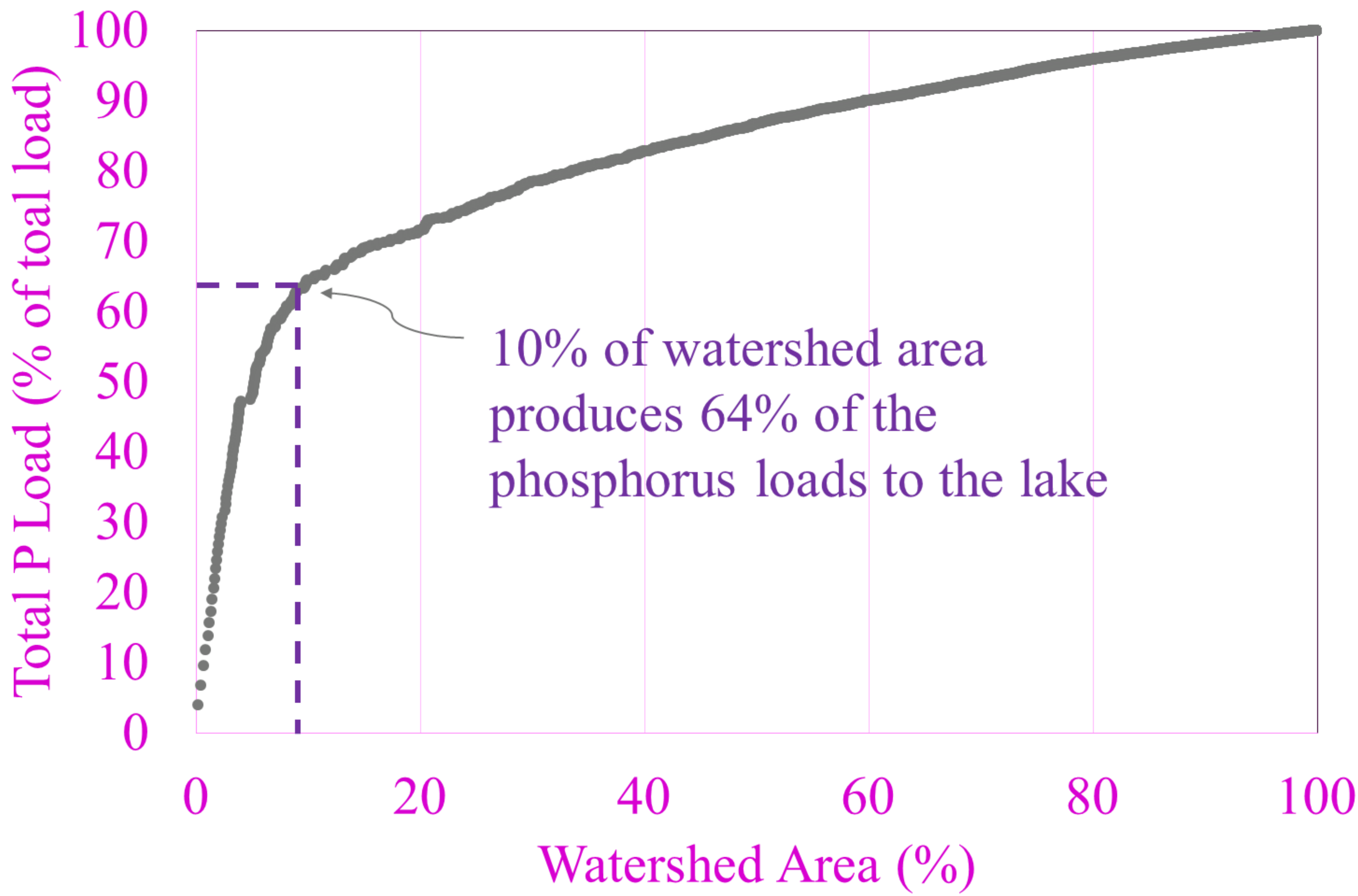


CSA Analysis: Total P Load by Land Use



Corn and lima beans contribute highest total loads, followed by winter wheat potato, and apples

CSA Analysis: Cumulative Watershed P Load



Alternative Management Practices

Alternative management practices currently being considered include:

- Reduced irrigation in orchards
- Fertilizer best practices (placement and rate)
- Apple orchard waste management
- Wetland restoration (point source and non point source P)
- Erosion control from agricultural land

Alternative Management Practices: Irrigation Code Modification

Current SWAT Code: Irrigation depth capped to field capacity when using outside source, resulting in lower than intended irrigation amount

Revised SWAT Code: Set to use allow user-specified depth (regardless of field capacity), resulting in intended irrigation amount

Code change impacted overall nutrient flux

Surface runoff from irrigation events currently a user-defined fraction of irrigation, not based on a mechanistic or empirical model

irrsub.f

```
case (5)   !! unlimited source
       vmm = sol_sumfc(j)
    end select
```

revision

```
case (5)   !! unlimited source
       vmm = irramt(j)
    end select
```

Alternative Management Practices: Orchard Irrigation Reduction

Current Irrigation Practice: 864 mm/year, simulated as manual irrigation in SWAT

Based on a UNDP soil sampling, recommendation is to apply either 318 mm (drip) to 454 mm (surface) of irrigation, simulated as auto-irrigation in SWAT

Based on a 30-year simulation under alternative practice:

- Average irrigation of 369 mm/yr
- Water use reduced by 57%
- Total annual P reduced by 26%
- Simulated biomass growth increased, potentially due to greater nutrient availability in the soil profile

Conclusions and Next Steps

A coupled SWAT-BATHTUB model for the Prespa Lake watershed was able to simulate the hydrology and water quality of tributary rivers and the lake

Preliminary results suggest that 10% of the landscape contributes 64% of the total P, indicating high potential for meaningful P reduction with targeted alternative practices

Initial evaluation of improved irrigation practices showed benefits in terms of water use savings and lower pollutant losses, with no effect on crop yield

Early estimates suggest that a reduction of total P load of ~40% would bring lake conditions solidly into the mesotrophic range

Additional management alternatives will be assessed in the coming months

Through the support of the UNDP, water quality monitoring will continue throughout the watershed, providing data for future model refinements

Thank you.

Acknowledgements:
Dimitar Sekovski, UNDP
Mary Watzin, North Carolina State University
Ordan Cukaliev and Cvetanka Popovska,
University of Ss. Cyril & Methodius

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