Projecting Changes in Water Quality in the Tennessee River Basin associated with Growing Biofuels

Gangsheng Wang[1]

Henriette Jager[1]

Latha Baskaran[1]

Tyler Baker[2], Craig Brandt[1]

[1]*Environmental Sciences,* Oak Ridge National Lab
[2]*Tennessee Valley Authority*

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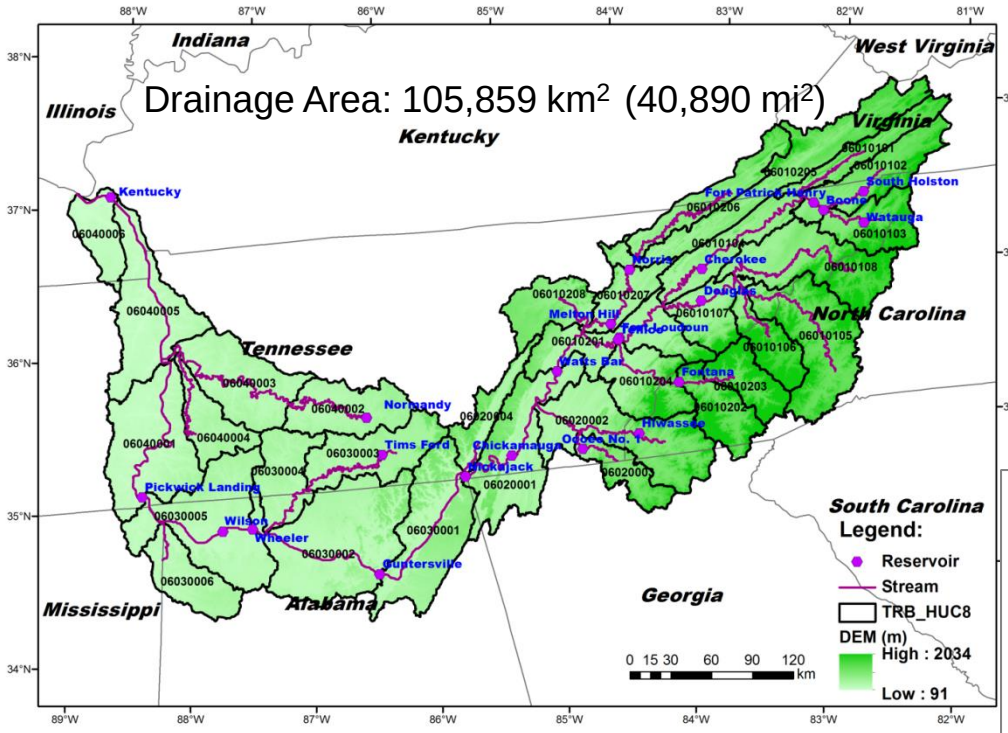
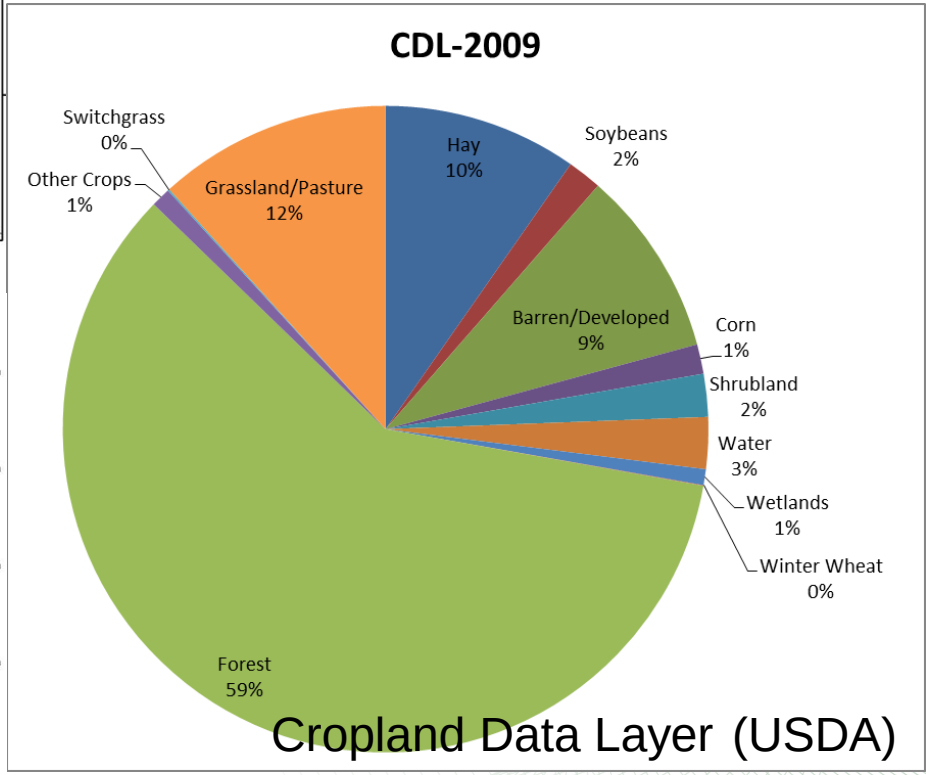
Tennessee River Basin (TRB)



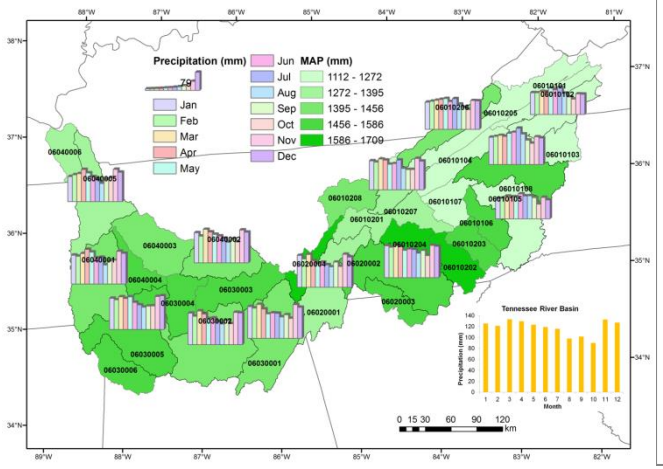
GOAL:

To guide the bioeconomy toward sustainable practices by understanding how alternative decisions influence water quantity/quality across spatial scales.

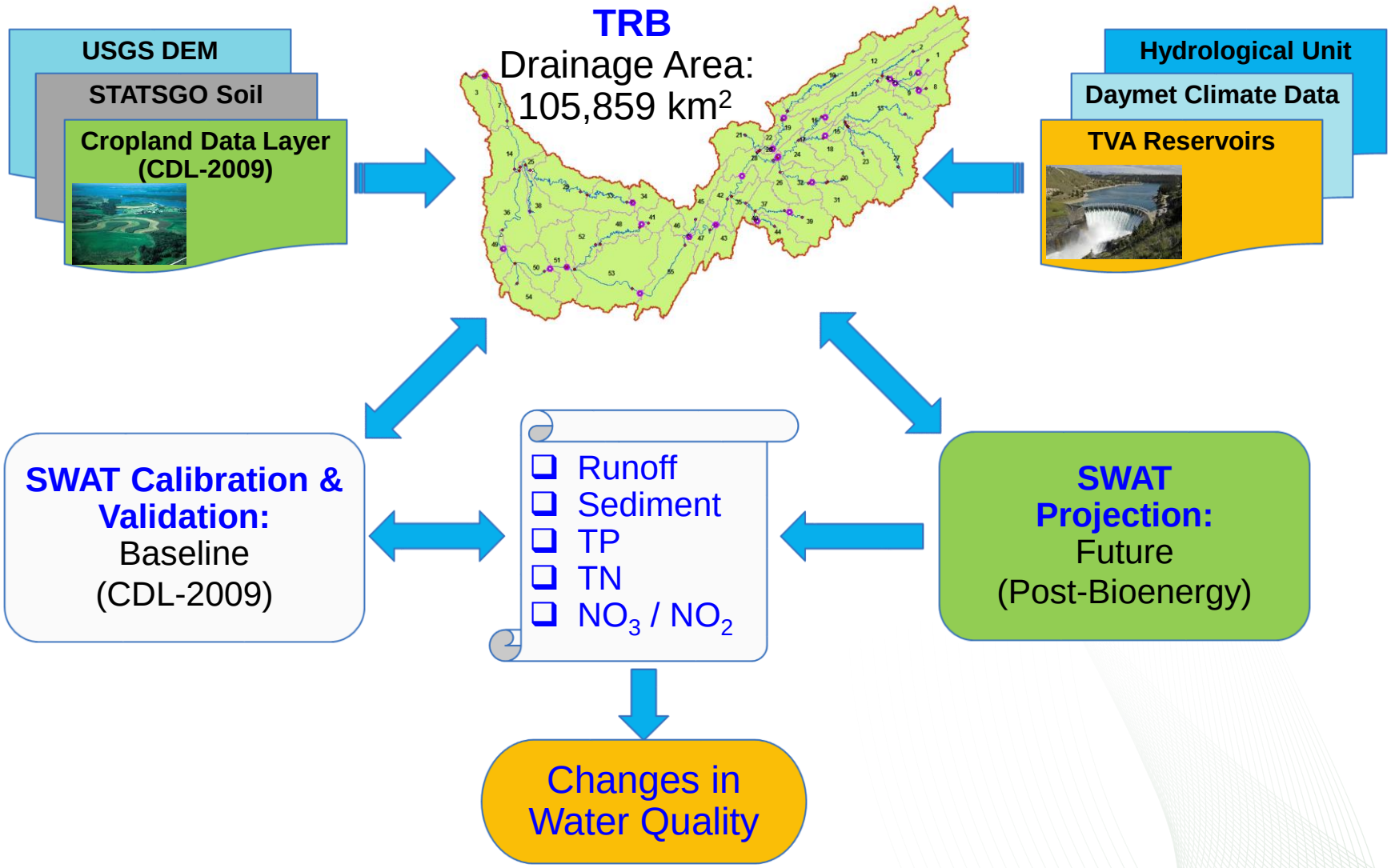


Cropland Data Layer (USDA)

Precipitation (1980–2011) (daymet)

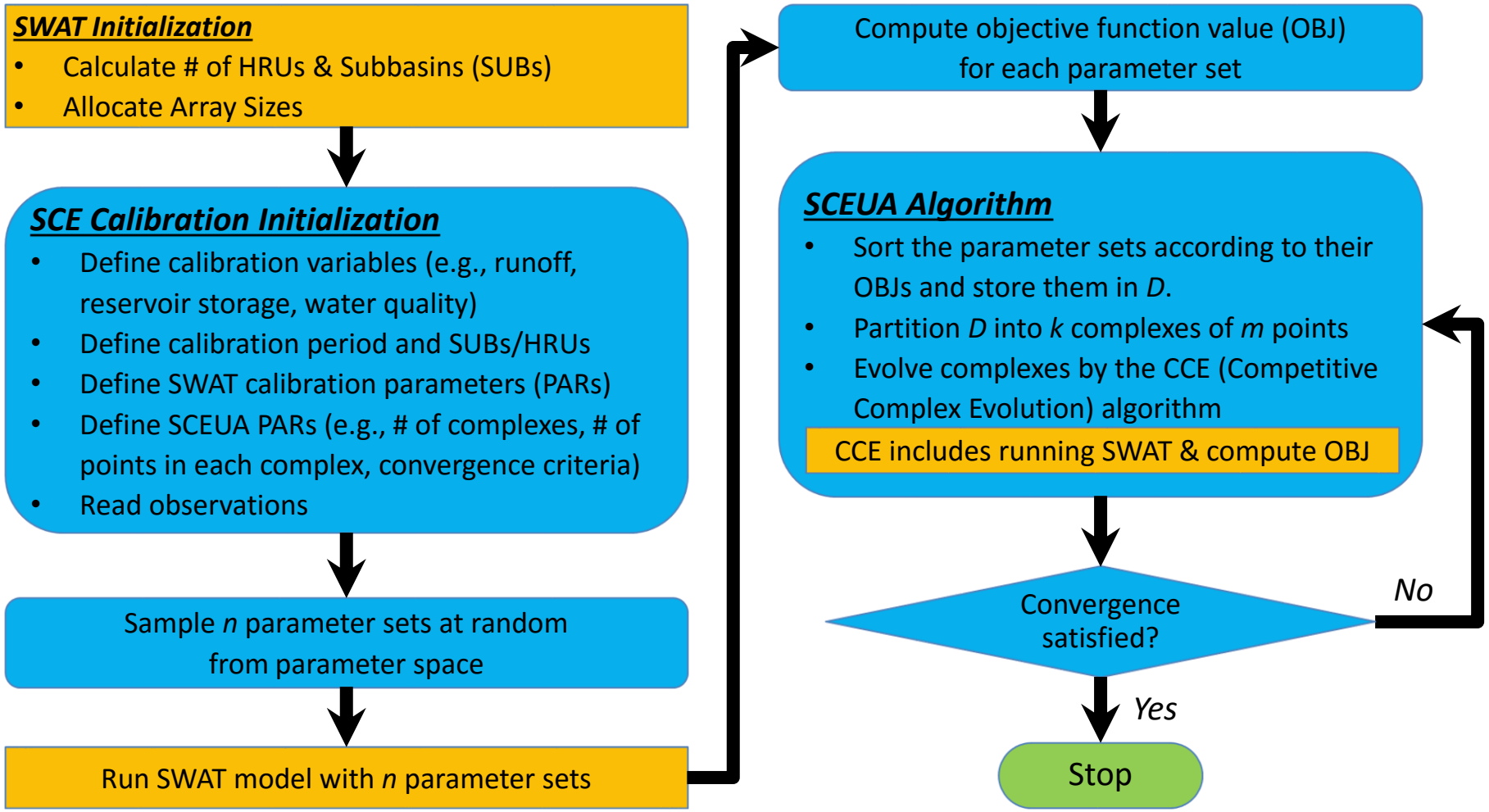


Methods


USGS DEM
STATSGO Soil
Cropland Data Layer (CDL-2009)
TRB
Drainage Area:
105,859 km2
Hydrological Unit
Daymet Climate Data
TVA Reservoirs
SWAT Calibration & Validation:
Baseline
(CDL-2009)
Runoff
Sediment
TP
TN
NO3 / NO2
SWAT Projection:
Future
(Post-Bioenergy)
Changes in Water Quality

Integration of SCEUA into SWAT:

https://github.com/wanggangsheng/SWATopt



SWAT: Soil & Water Assessment Tool (Arnold & Fohrer, 2005)
SCE: Shuffled Complex Evolution (Duan et al., 1992)

SWAT parameters for calibration

No	Parameter*	Description	Default	Min	Max	Input file	Fortran code
1	CN2	Initial SCS curve number II	85	35	98	*.mgt	Readmgt.f
2	ESCO	Soil evaporation compensation factor	0.95	0.01	1	*.hru	Readhru.f
3	EPCO	Plant uptake compensation factor	1	0.01	1	*.hru	Readhru.f
4	OV_N	Manning's n value for overland flow	0.1	0.01	0.6	*.hru	Readhru.f
5	CH_N2	Manning's n value for main channel	0.014	0.01	0.5	*.rte	Readrte.f
6	CH_K2	Channel effective hydraulic conductivity (mm/hr)	0.001	0.001	150	*.rte	Readrte.f
7	ALPHA_BF	Baseflow alpha factor (days)	0.048	0.001	1	*.gw	Readgw.f
8	GW_DELAY	Ground water delay (days)	31	0.0001	500	*.gw	Readgw.f
9	RCHRG_DP	Deep aquifer percolation fraction	0.05	0.0001	1	*.gw	Readgw.f
10	GW_REVAP	Groundwater revap coefficient	0.02	0.02	0.2	*.gw	Readgw.f
11	GW_SPYLD	Specific yield for shallow aquifer (m^3/m^3)	0.003	0.0001	0.4	*.gw	Readgw.f
12	SOL_AWC	Available water capacity (mm H_2O/mm soil)	0.2	0.01	0.4	*.sol	Readsol.f
13	SOL_K	Saturated hydraulic conductivity (mm/h)	10	0.01	100	*.sol	Readsol.f
14	SURLAG	Suface runoff lag coefficient (days)	4	0.5	12	sub.lag	Readhru.f
15	SPCON	Linear re-entrainment parameter	0.0001	0.0001	0.01	basins.bsn	Readbsn.f
16	SPEXP	Exponent re-entrainment parameter	1	1	2	basins.bsn	Readbsn.f
17	PRF	Adjustment factor for sediment routing in the main channel	1	0.001	2	basins.bsn	Readbsn.f
18	ADJ_PKR	Adjustment factor for sediment routing in tributary channels	1	0.5	2	basins.bsn	Readbsn.f
19	CH_COV	Channel cover factor	0.001	0.001	1	*.rte	Readrte.f
20	CH_EROD	Channel erodibility factor	0.001	0.001	1	*.rte	Readrte.f
21	USLE_K	Soil erodability factor	0.28	0.01	0.65	*.sol	readsol.f
22	BIOMIX	Biological mixing coefficiency	0.2	0.01	1	*.mgt	Readmgt.f
23	RSDCO	Residue decomposition factor	0.05	0.02	0.1	basins.bsn	Readbsn.f
24	NPERCO	Nitrogen percolation factor	0.2	0.001	1	basins.bsn	Readbsn.f
25	N_UPDIS	N uptake distribution parameter	20	0.001	100	basins.bsn	Readbsn.f
26	NSETLR	N settling rate in reservoir (m/yr), Line 7 & 8	5.5	1	15	*.lwq	Readlwq.f
27	SHALLST_N	Concentration of NO_3 in groundwater (mg N/L)	0.0001	0.0001	1000	*.gw	Readgw.f
28	ERORGN	Organic N enrichment for sediment	0.001	0.001	5	*.hru	Readhru.f
29	SOL_ORGN	Initial organic N concentration (mg N kg^{-1} soil)	0.01	0.01	50	*.chm	Readchm.f
30	SOL_NO3	Initial NO_3 concentration in the soil layer (mg N kg^{-1} soil)	0.01	0.01	50	*.chm	Readchm.f
31	PPERCO	Phosphorus percolation factor (10 m^3 Mg^{-1})	10	10	17.5	basins.bsn	Readbsn.f
32	PHOSKD	Phosphorus soil partitioning coefficient (m^3 Mg^{-1})	175	100	200	basins.bsn	Readbsn.f
33	PSP	P sorption coefficient	0.4	0.01	0.7	basins.bsn	Readbsn.f
34	PSETLR	P settling rate in reservoir (m/yr), Line 5 & 6	10	2	20	*.lwq	Readlwq.f
35	BC4	Rate const for mineralization of organic P to dissolved P (1/d)	0.35	0.01	0.7	*.swq	Readswq.f
36	RS5	Organic P settling rate (1/d)	0.05	0.001	0.1	*.swq	Readswq.f
37	ERORGP	Organic P enrichment ratio with sediment loading	0.001	0.001	5	*.hru	readhru.f
38	SOL_ORGP	Initial organic P (mg P kg^{-1} soil)	0.01	0.01	50	*.chm	Readchm.f
39	SOL_SOLP	Initial soluble P concentration in the soil layer (mg P kg^{-1} soil)	5	0.01	50	*.chm	Readchm.f

*Four groups of parameters: No. 1–14: Water quantity; No. 15–21: Sediment; No. 22–30: Nitrogen; No. 31–39: Phosphorus.

Calibration/Validation of Runoff (USGS)

of HUC8: 32

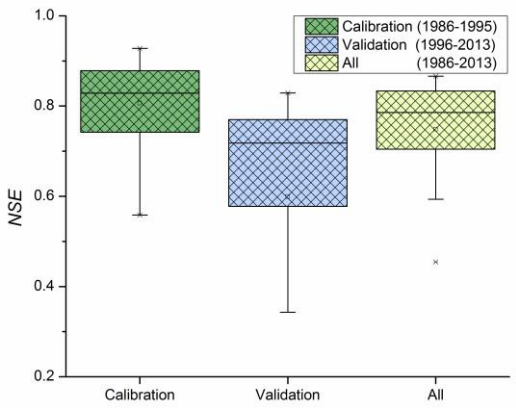
# of subbasins: 55

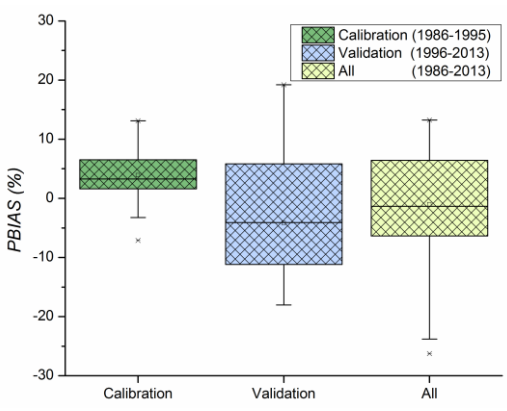
Each HUC8 contains 1–4 subbasins

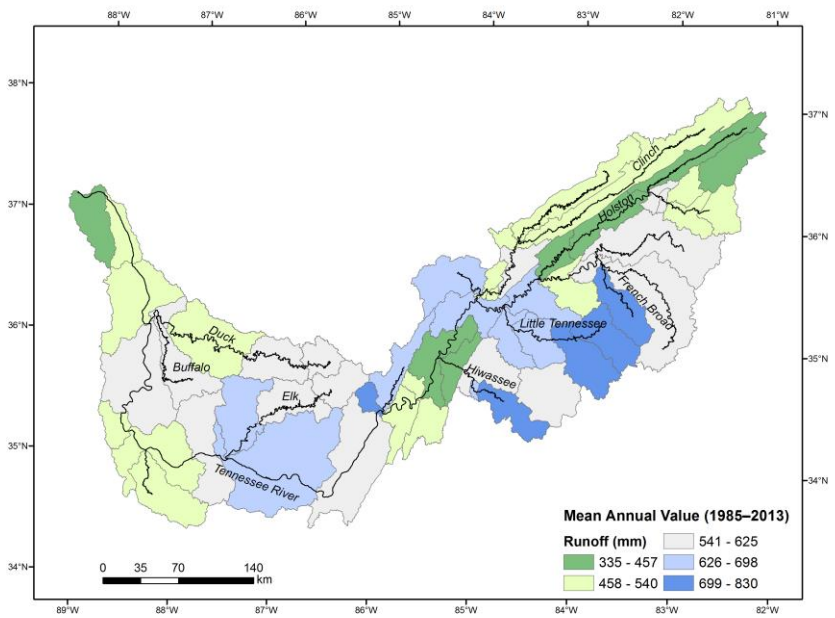
Spin-up: 1-yr: 1985

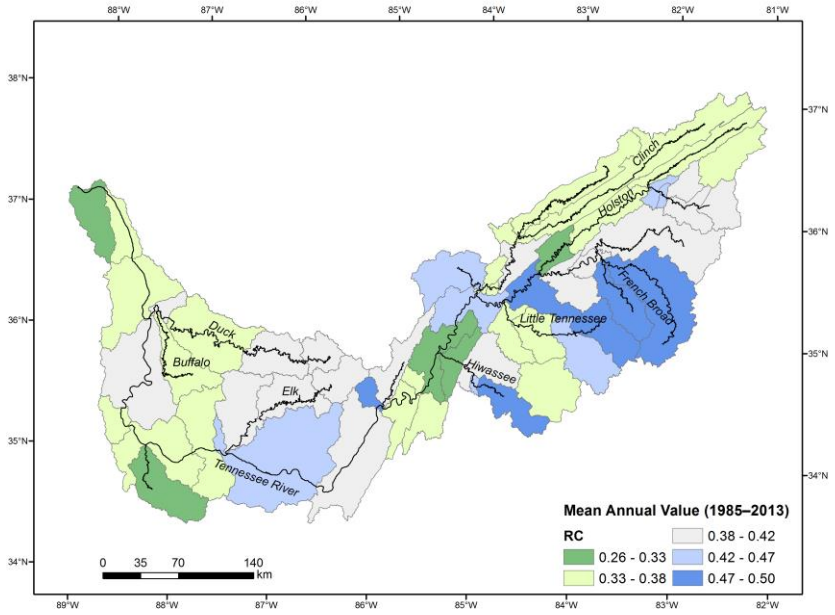
Calibration: 10-yr: 1986–1995

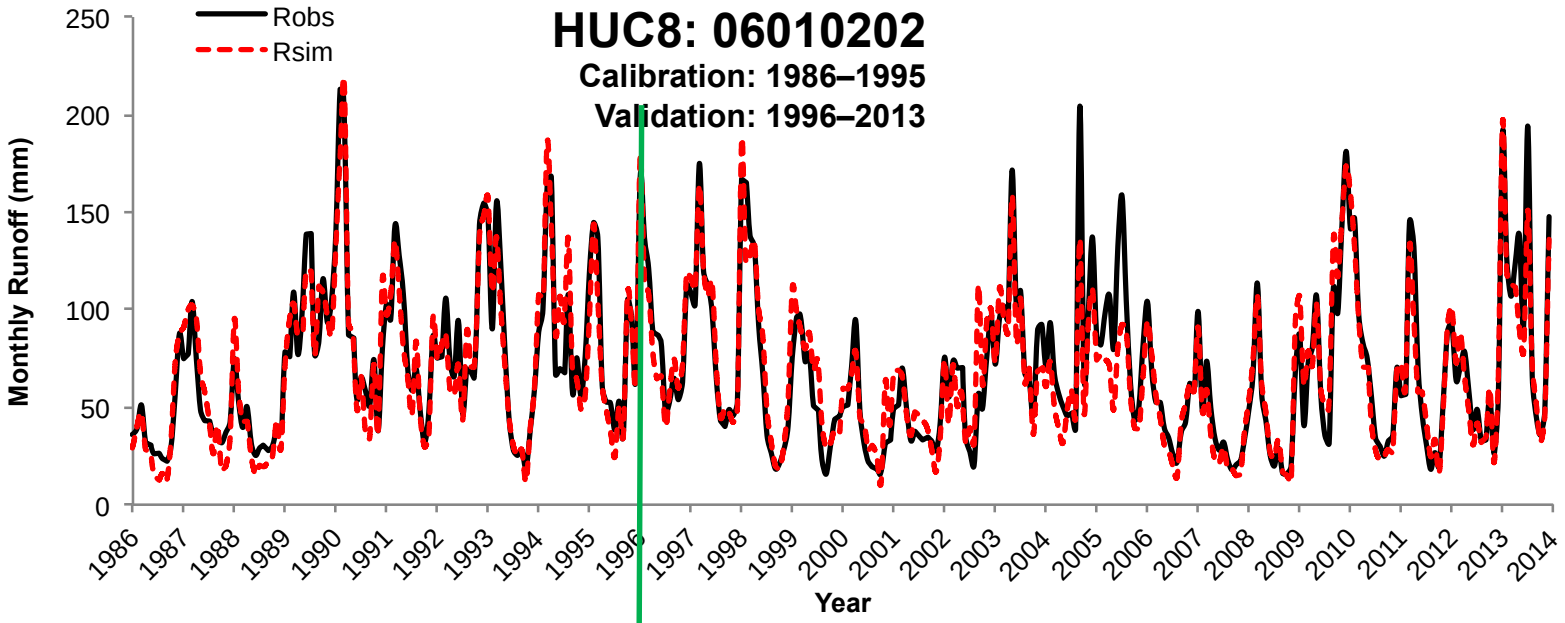
Validation: 18-yr: 1996–2013

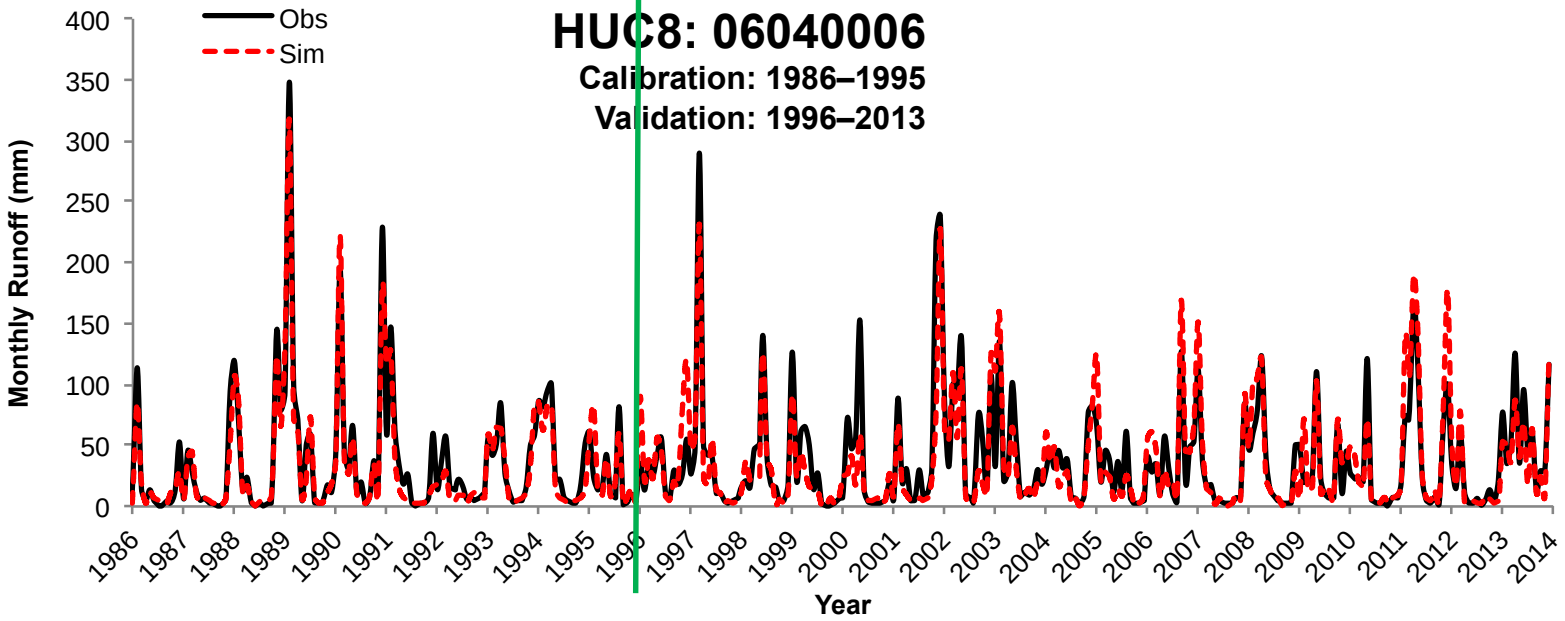






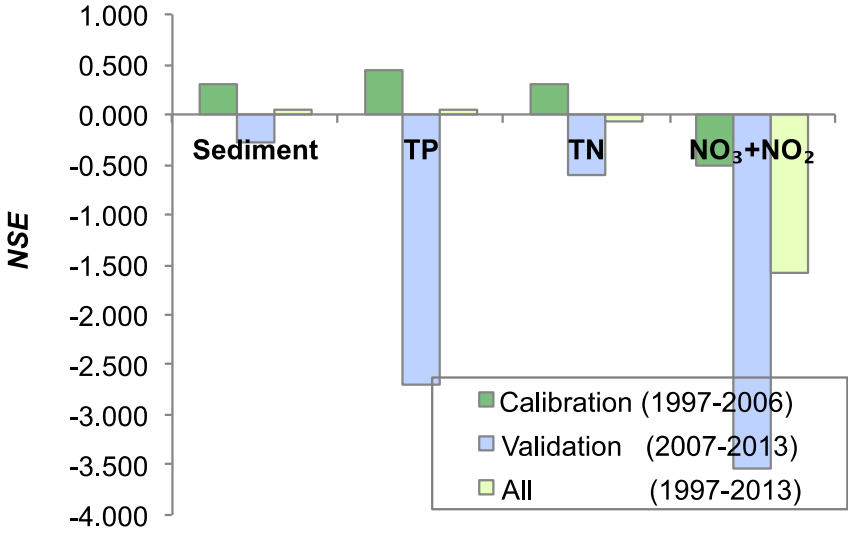


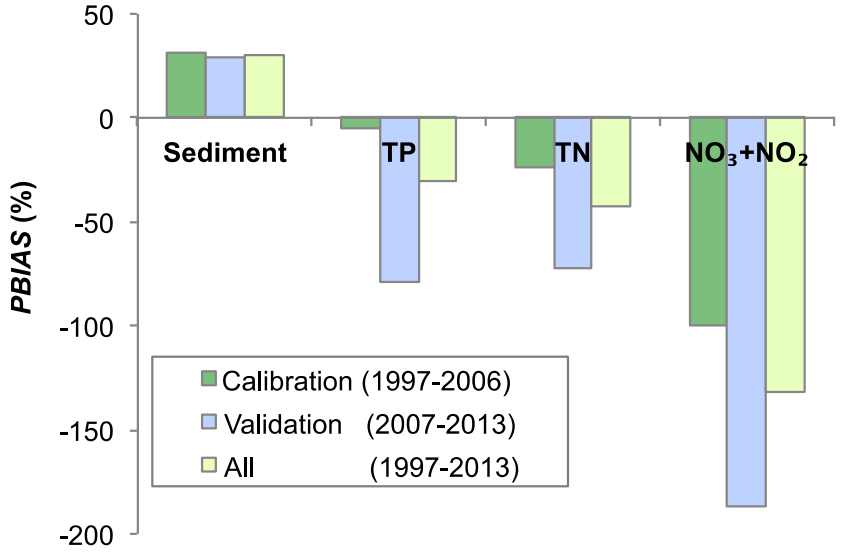

Robs
Rsim
HUC8: 06010202
Calibration: 1986–1995
Validation: 1996–2013
Monthly Runoff (mm)
Year
Calibration
Validation

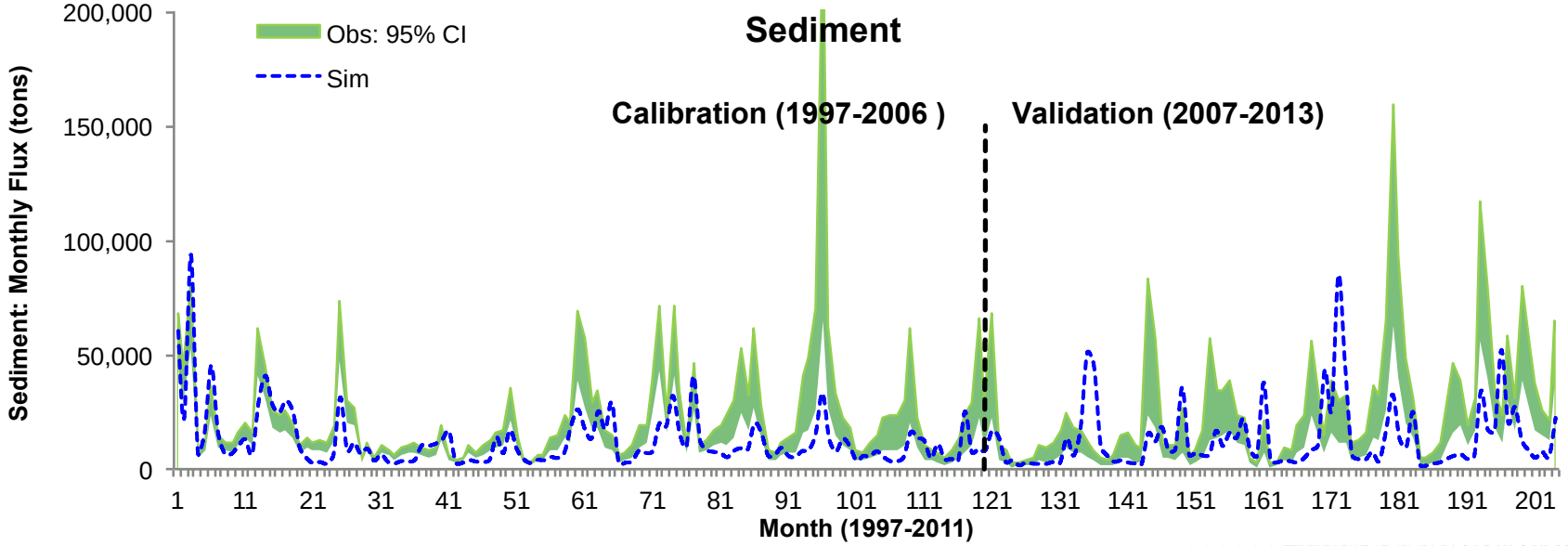

Obs
Sim
HUC8: 06040006
Calibration: 1986–1995
Validation: 1996–2013
Monthly Runoff (mm)
Year

Calibration/Validation of Water Quality

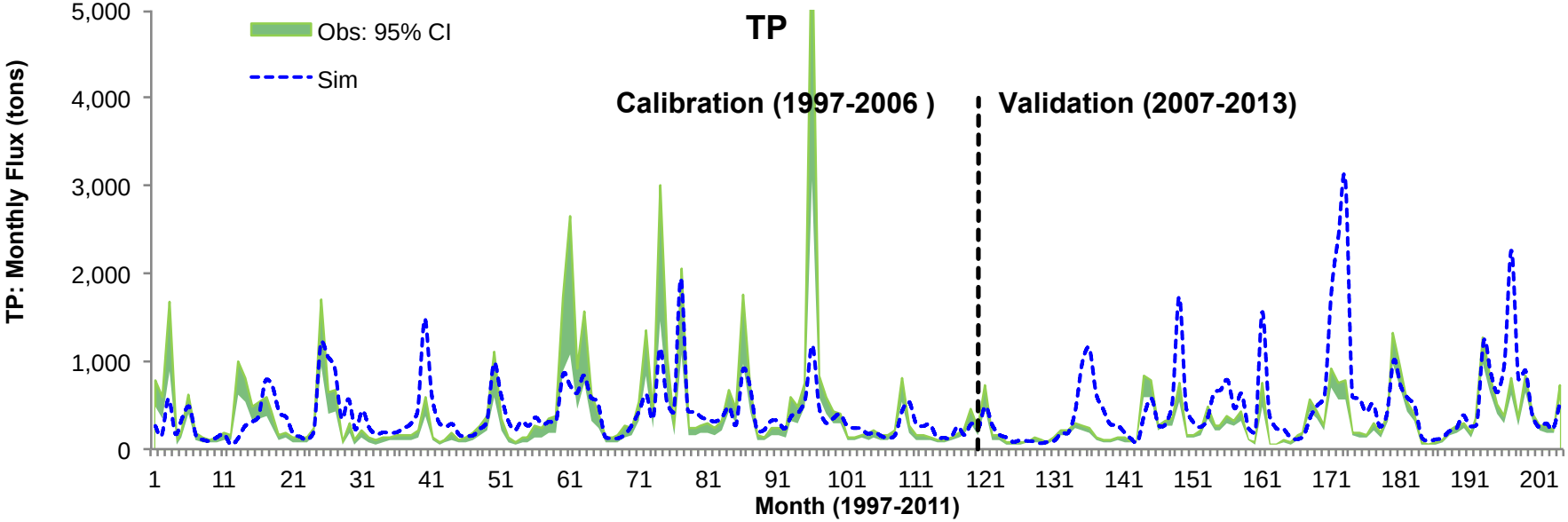
Tennessee River at Highway 60 near Paducan, KY (USGS Station ID 03609750)

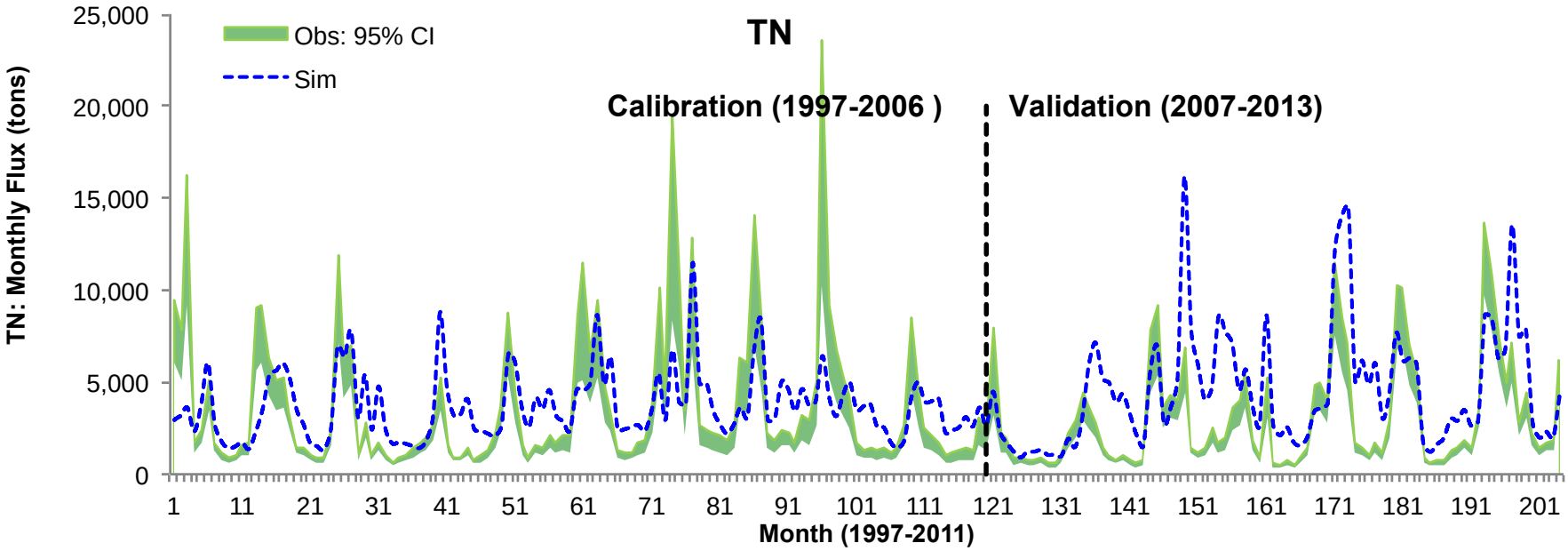






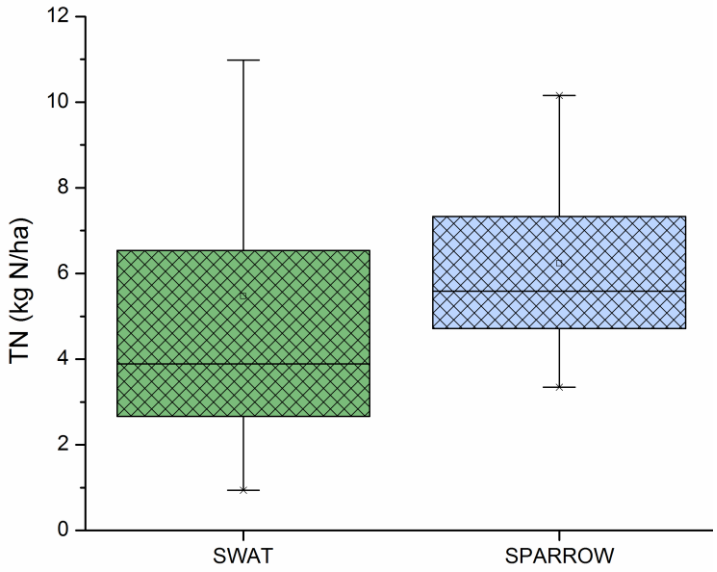
Calibration/Validation of Water Quality

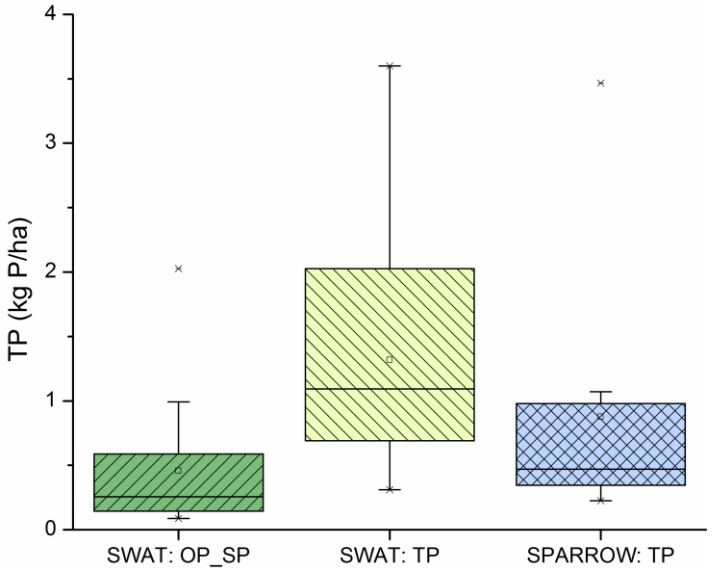


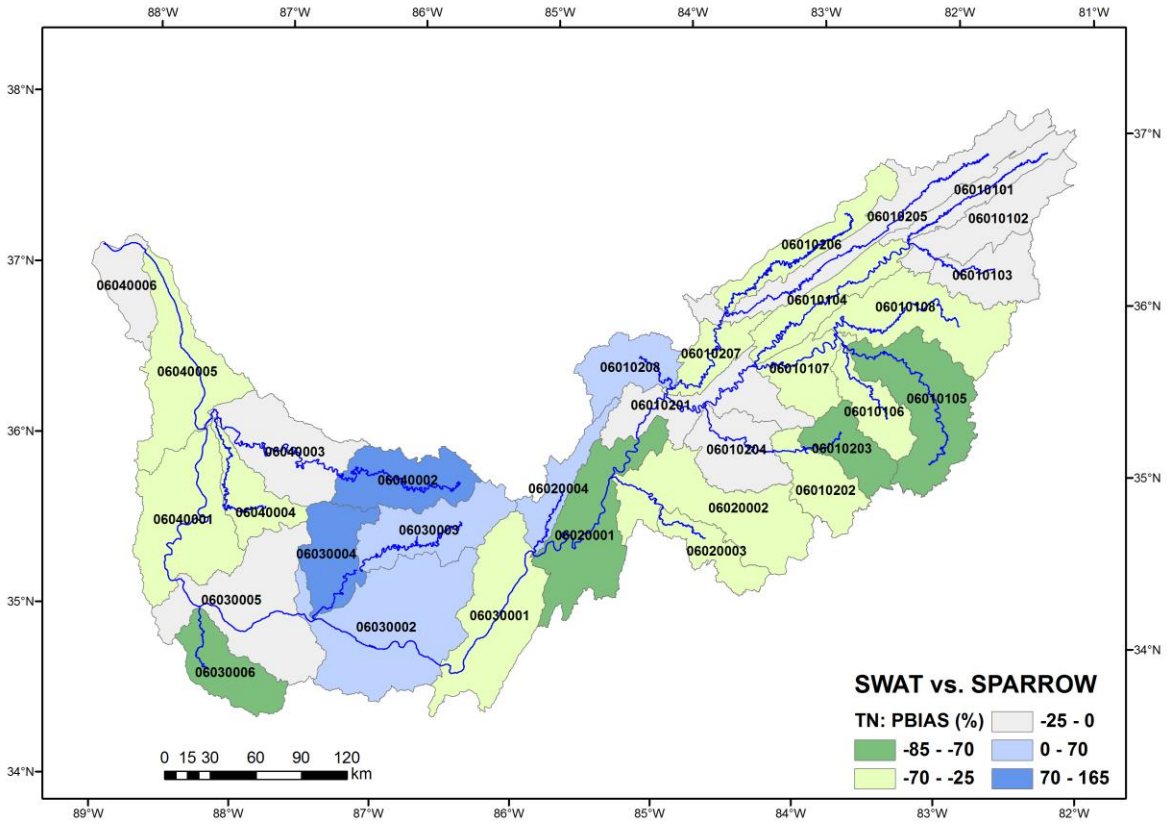


SWAT (1985-2013) vs. SPARROW (1975-2004)

Percent Bias (%) in long-term means







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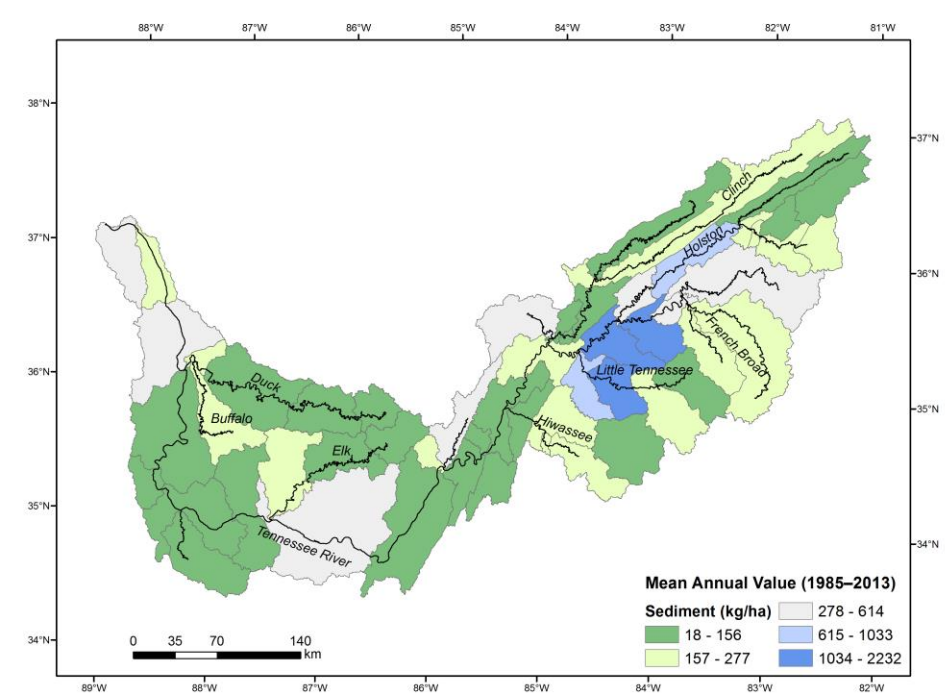
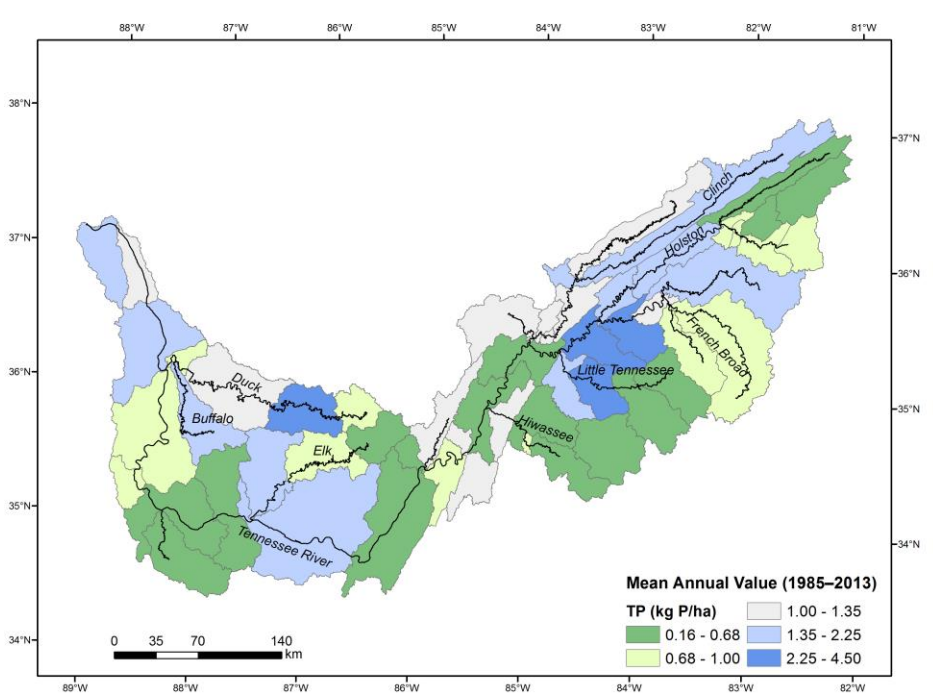
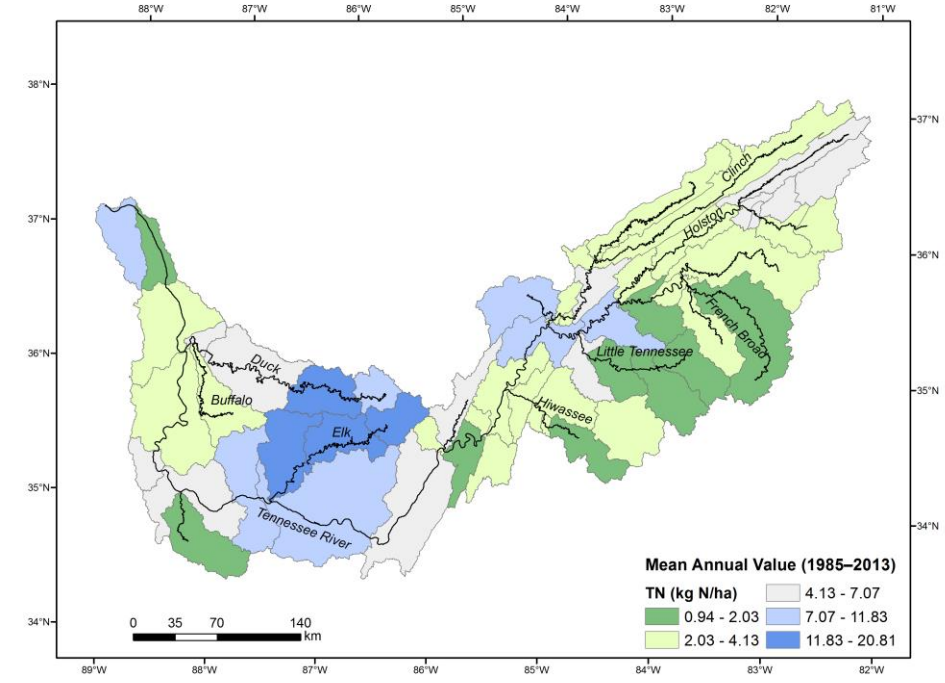
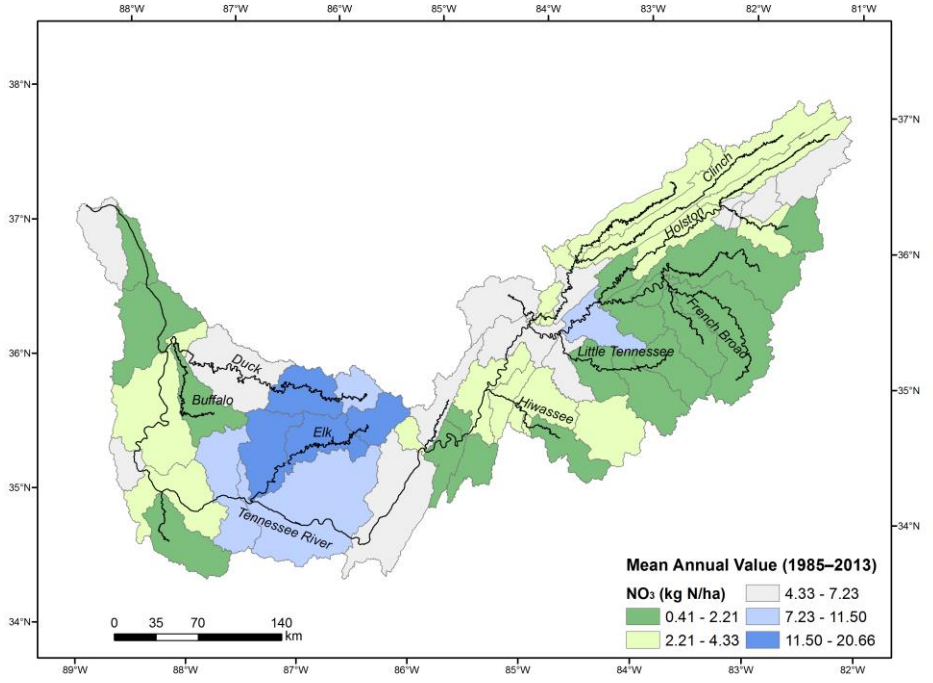
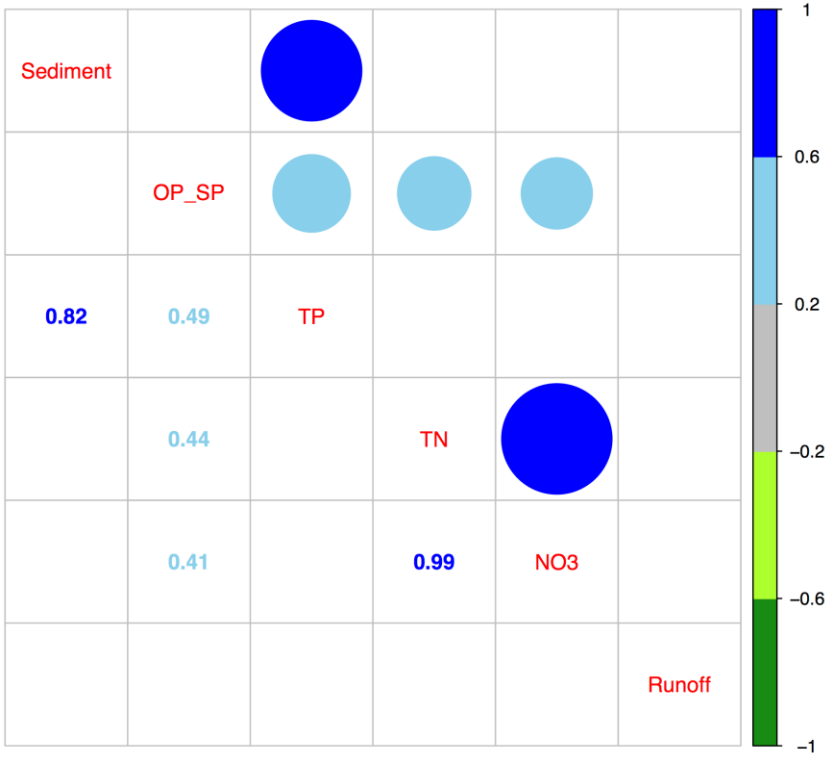

Clinch
Holston
French Broad
Little Tennessee
Duck
Buffalo
Elk
Hiwassee
Tennessee River
Mean Annual Value (1985–2013)
Sediment (kg/ha)
18 - 156
157 - 277
278 - 614
615 - 1033
1034 - 2232
0 35 70 140
km

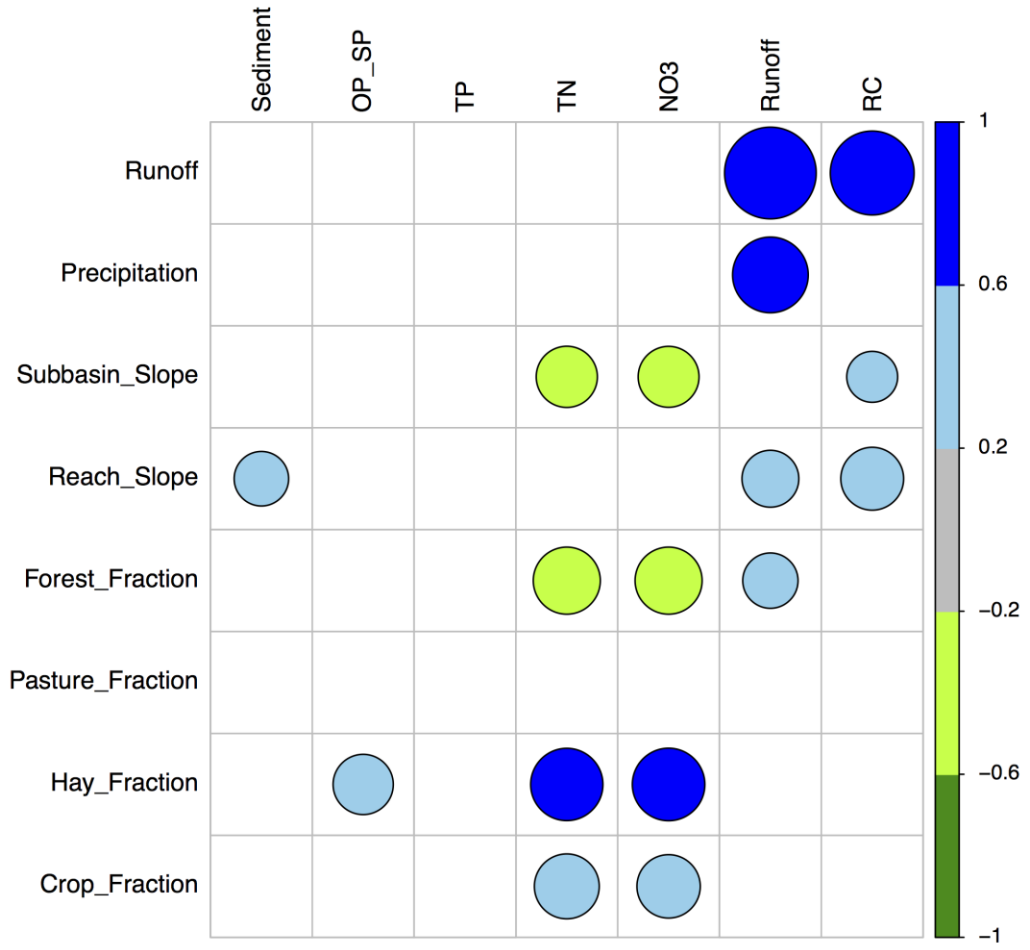

Clinch
Holston
French Broad
Little Tennessee
Duck
Buffalo
Elk
Hiwassee
Tennessee River
Mean Annual Value (1985–2013)
TP (kg P/ha)
0.16 - 0.68
0.68 - 1.00
1.00 - 1.35
1.35 - 2.25
2.25 - 4.50
0 35 70 140
km


Clinch
Holston
French Broad
Little Tennessee
Duck
Buffalo
Elk
Hiwassee
Tennessee River
Mean Annual Value (1985–2013)
TN (kg N/ha)
0.94 - 2.03
2.03 - 4.13
4.13 - 7.07
7.07 - 11.83
11.83 - 20.81
0 35 70 140
km


Clinch
Holston
French Broad
Little Tennessee
Duck
Buffalo
Elk
Hiwassee
Tennessee River
Mean Annual Value (1985–2013)
NO3 (kg N/ha)
0.41 - 2.21
2.21 - 4.33
4.33 - 7.23
7.23 - 11.50
11.50 - 20.66
0 35 70 140
km

Spatial Correlation Analyses

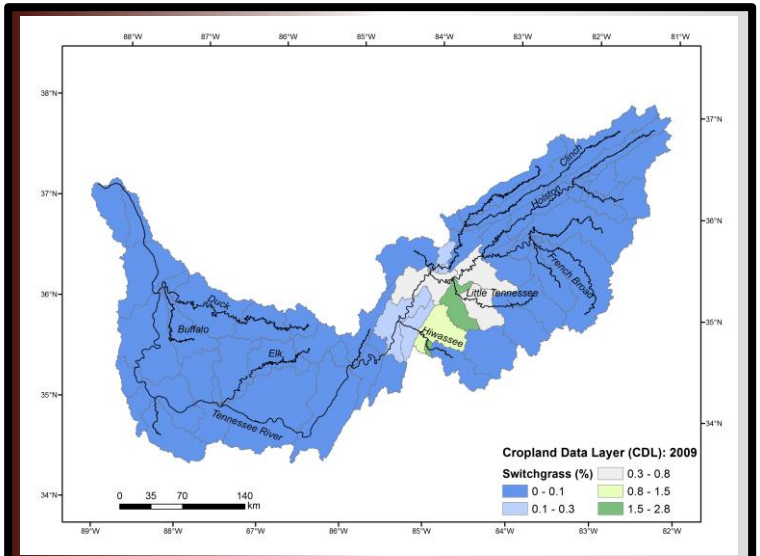


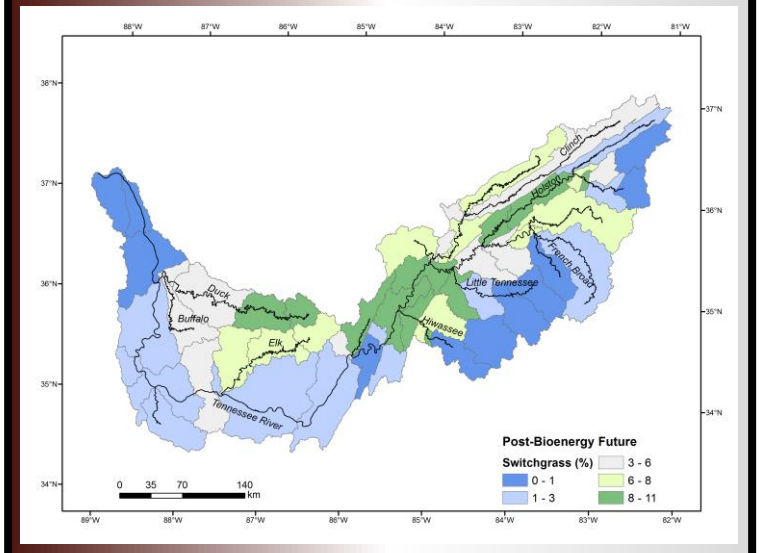


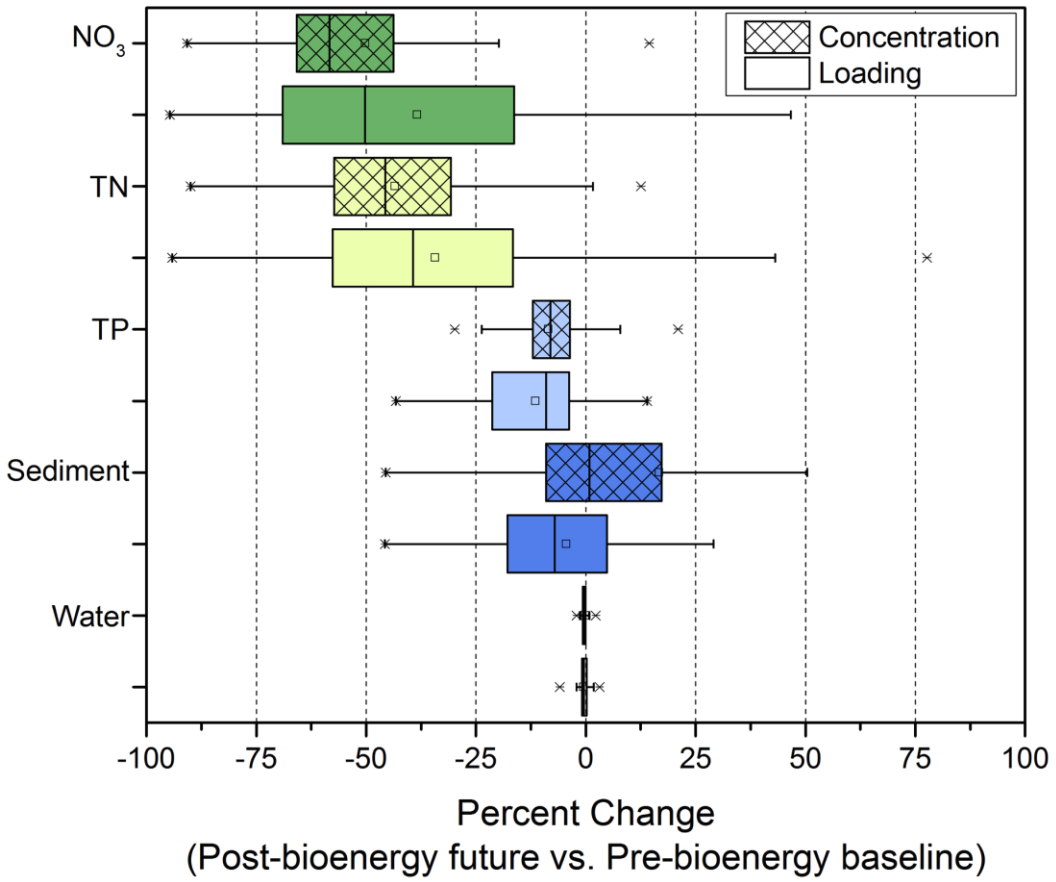
OP_SP = Organic P + Soluble P

TP = OP_SP + Sediment Mineral P

Results: % changes due to land use change







Summary

❖ **Methods:**

- TRB SWAT modeling with configuration of reservoirs.
- Auto-Calibration tools for multi-variables at multi-sites.
- Calibration and validation against HUC8-Runoff, temporal LOADEST and spatial SPARROW water quality datasets.

❖ **Controlling Factors:**

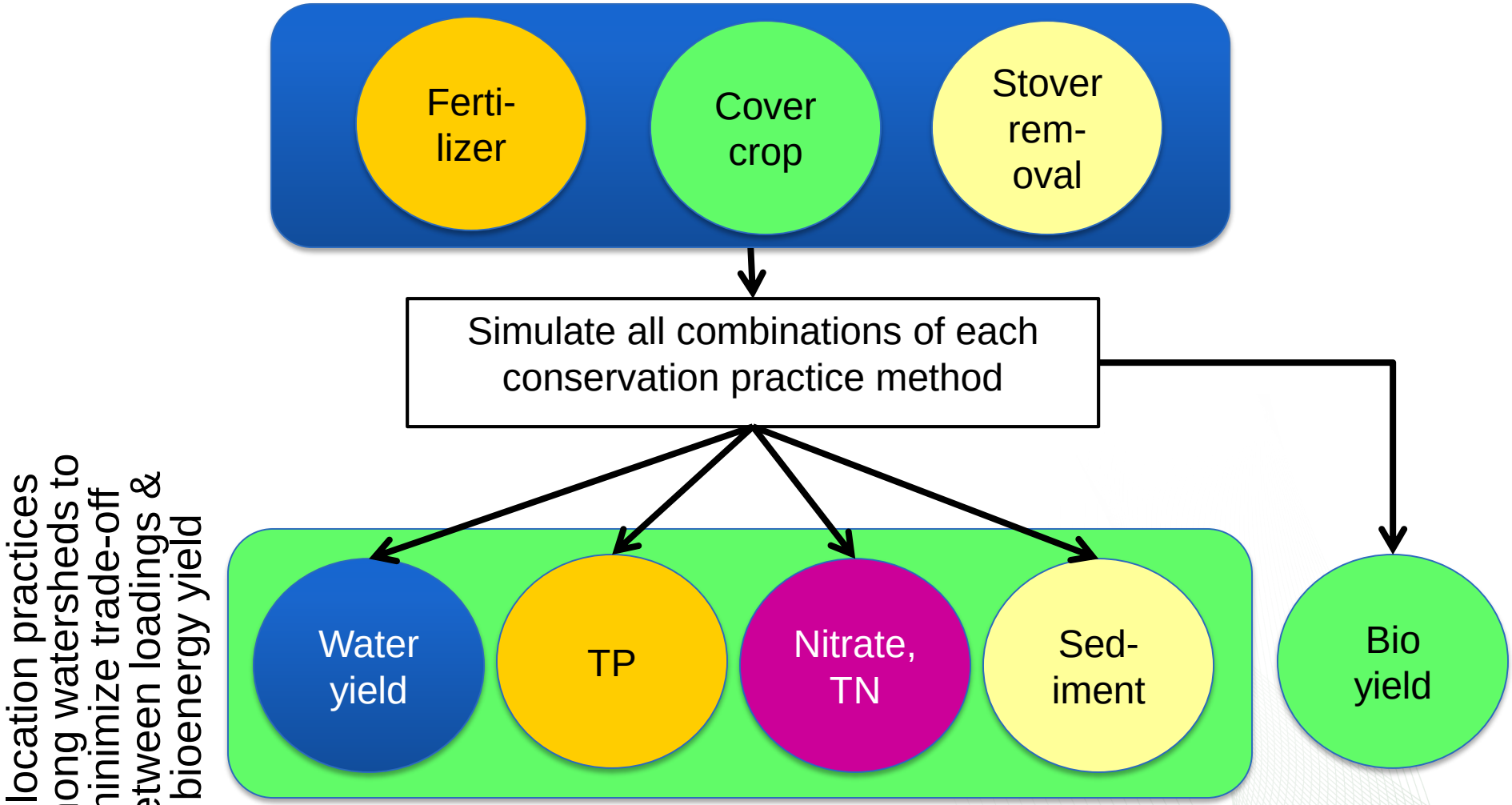
- Runoff was primarily controlled by precipitation.
- sediment was controlled by topography.
- NO_3 and soluble P were highly influenced by land management, particularly fertilization of croplands.

❖ **Post-Bioenergy Future vs. Pre-Bioenergy Baseline:**

- TRB holds promise for producing cellulosic feedstocks that enhance water quality.

Next Steps

Billion Ton Sustainability (Water indicators)



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  - Shih-Chieh Kao (ORNL)
  - Sujithkumar Surendran Nair (ORNL)