Benefits of Forests for Water: Exploring Effects of Land Use Change in the San Jacinto Watershed, Texas

International Soil and Water Assessment Tool (SWAT) Conference

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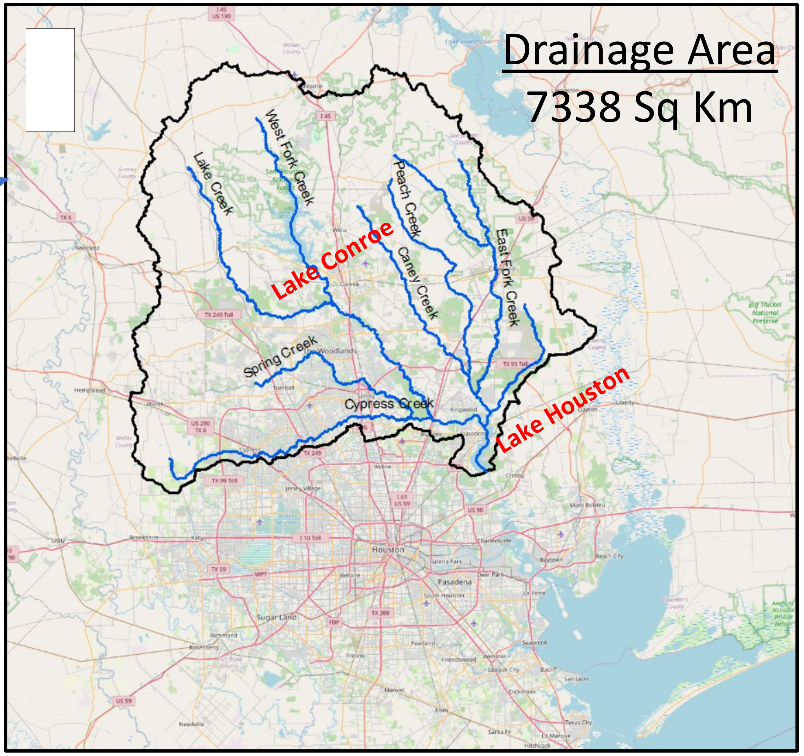
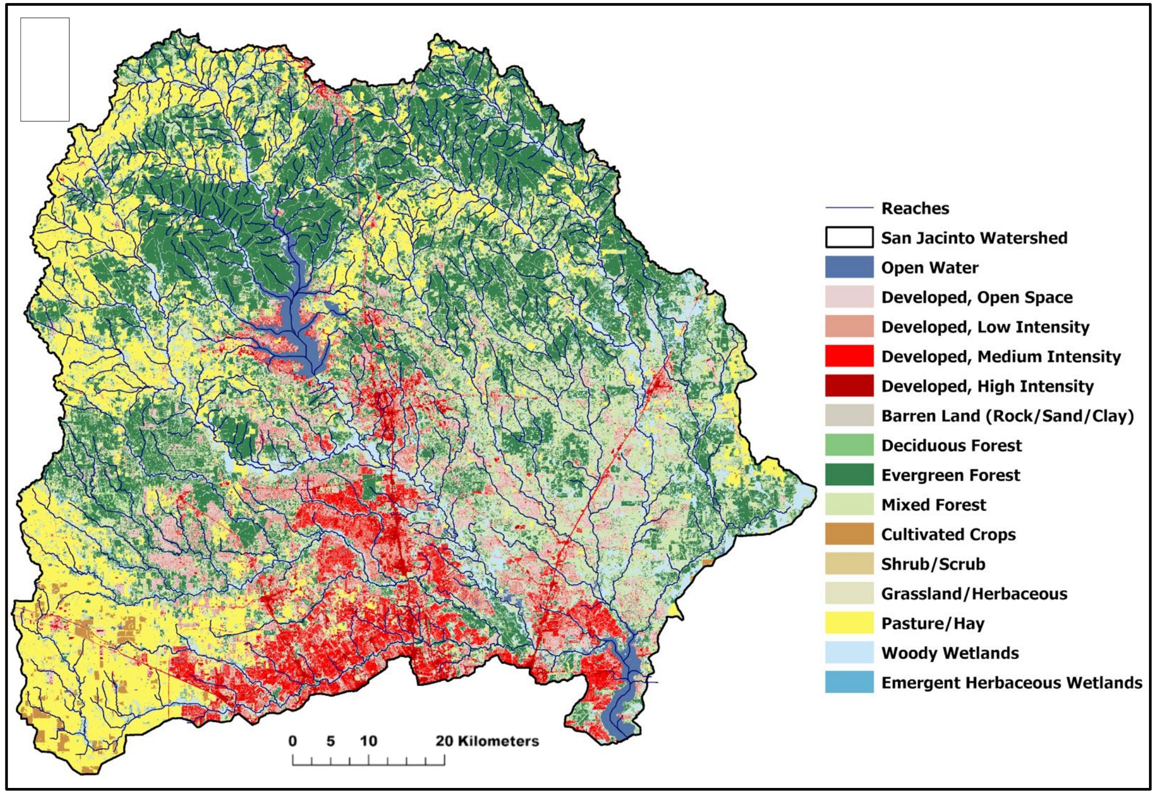
Background

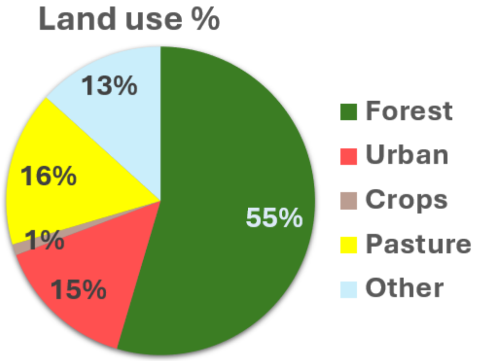
Location of the watershed



Vital water resource for the Houston metropolitan area



2020 National Land Cover Database (NLCD)



- Rapid urbanization northward and westward within the watershed → sustainability of water supply
- Significant challenges from severe weather extremes; 2011 drought, 2017 Hurricane Harvey inundation → rapid urbanization may increase the flood risks in future

Objectives

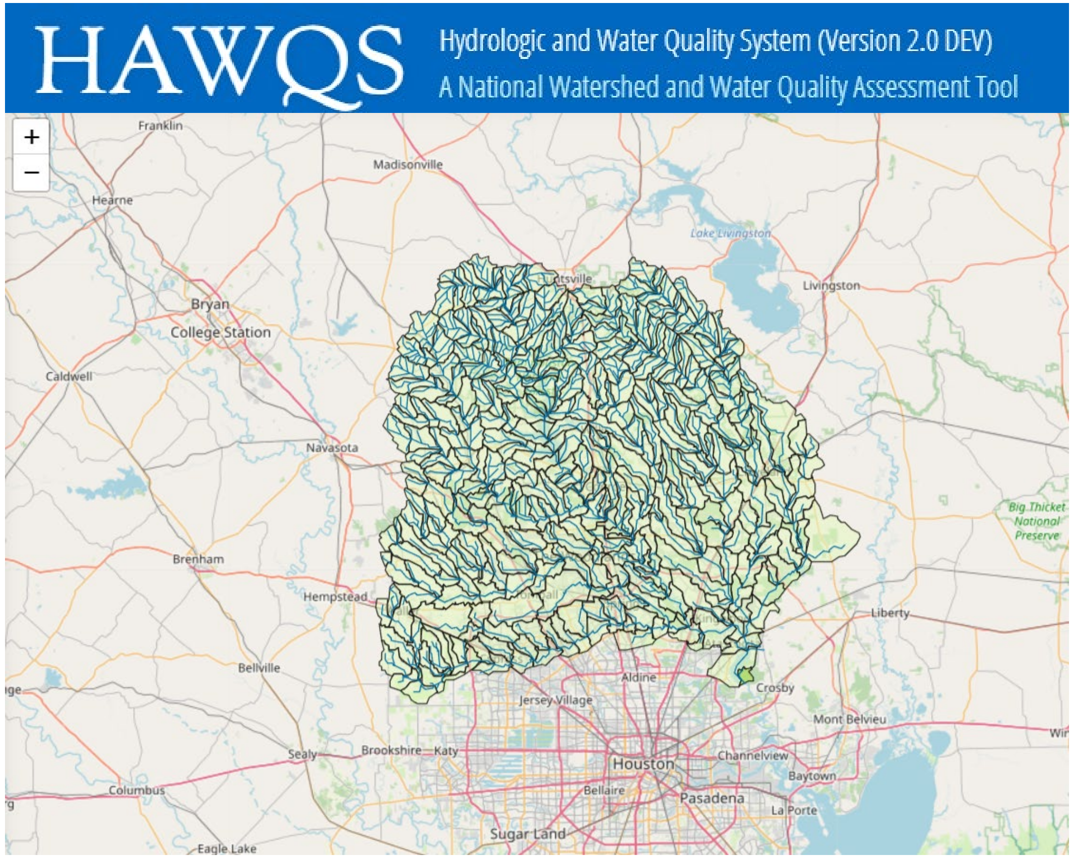
- Assess how urbanization will affect the watershed hydrology and water quality
    - ➢ Quantifying the impacts of projected future land use changes on water quantity in the streams and inflow to the reservoirs.
    - ➢ Identify sensitive areas in the watershed that show strong responses to the land use changes and their impacts on stream water quality.

Methodology

Model setup

Calibration

Projected Land use scenarios



HAWQS_2.0_Technical_Documentation.pdf (tamu.edu)

- Total no of sub-watersheds: 333
- Hydrologic Response Unit (HRUs) : 27888

Model Inputs

- Elevation (10 m DEM)
- Predefined stream network
- Predefined sub watershed boundary (HUC 14)
- Soil database (NRCS-SSURGO)
- Land use (NLCD)
- Daily weather data (PRISM)
- Lake Conroe Reservoir operation rules
- Point Source data (discharge, P and N)

Hydrologic Unit code (HUC) 14

Methodology

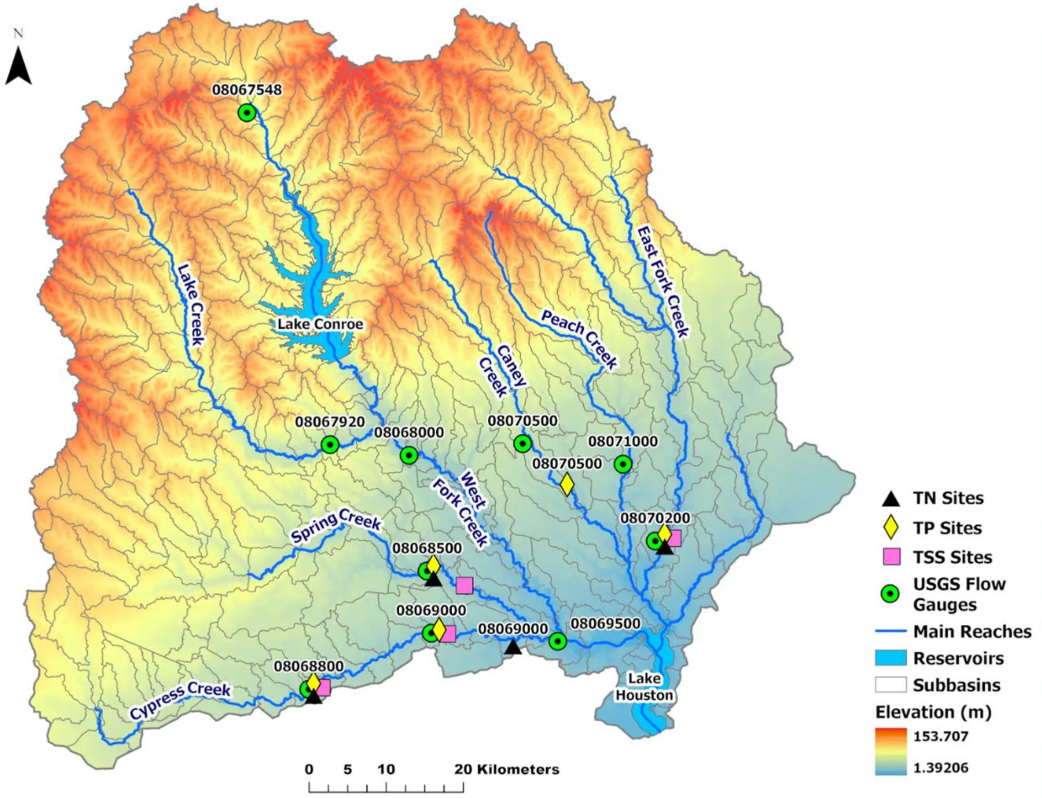
Model setup

↓

Calibration

↓

Projected Land u scenarios



SWAT-CUP

Flow → Sediment Yield → TP and TN

Flow calibration

2000-2020 (Daily Scale)
2 years (1998-1999) warm up period

Sediment & Nutrient

(Monthly Scale)
(Load Estimator (LOADEST))

- Cypress Creek (Urban Dominated)
- East Fork Creek , Lake Creek and upstream to Lake Conroe (Forest dominated)
- Spring creek (Mixed Type)

https://water.usgs.gov/software/loadest/

Methodology

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Projected Land use scenarios

USDA Resource Planning Act (RPA) Assessment Land Use Projections (2020-2070)

https://research.fs.usda.gov/inventory/rpaa/2020

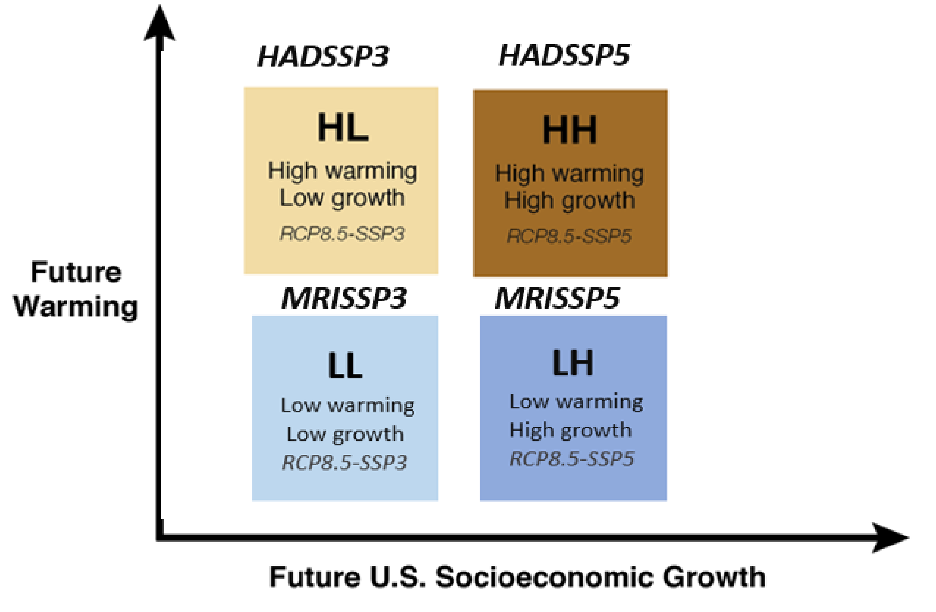
GCM

MRI-CGCM3 (low warm)
HadGEM2-ES (hot)

SSPs

SSP3 (low GDP and pop growth)
SSP5 (high GDP and pop growth)

Land use Projections (2020-2070)



U.S. DEPARTMENT OF AGRICULTURE (USDA)

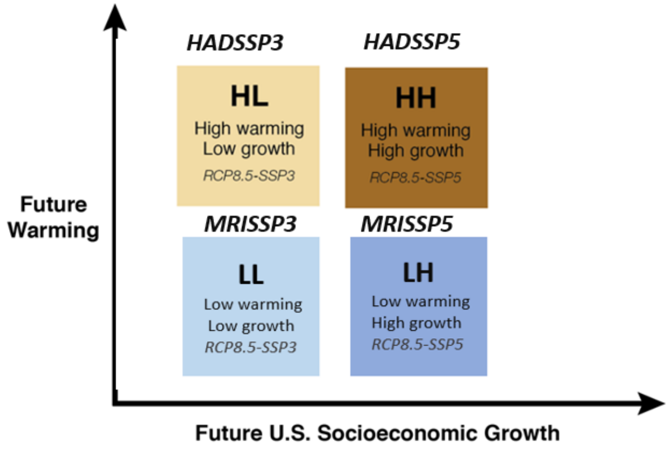
SSPs (**Shared Socioeconomic Pathway**)
GCM (**General Circulation Models)**

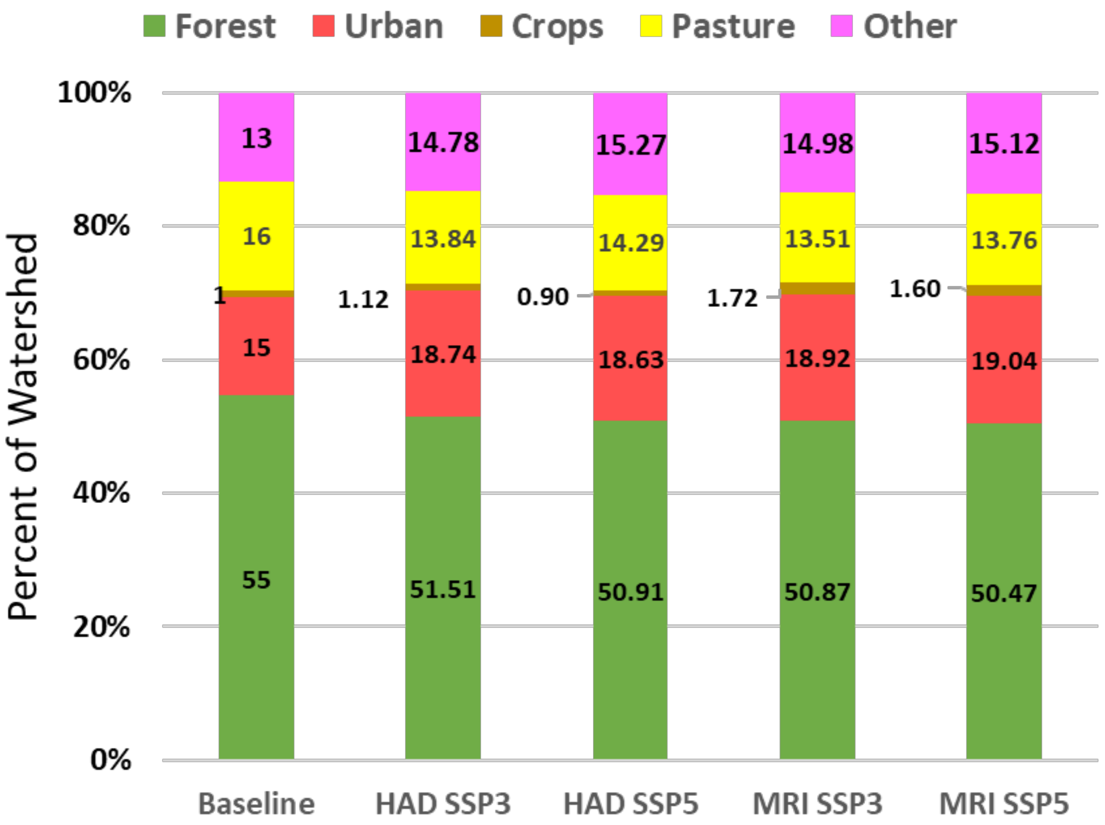
Methodology

Model setup

Calibration

Projected Land use scenarios





- The percentage of forest (green) decreased by 3.5% to 4.53% from baseline.
- Pastureland (yellow) decreased by 1.49 % to 2.49%.
- The urban area (red) **increases** from 3.63% to 4.04% across the scenarios.

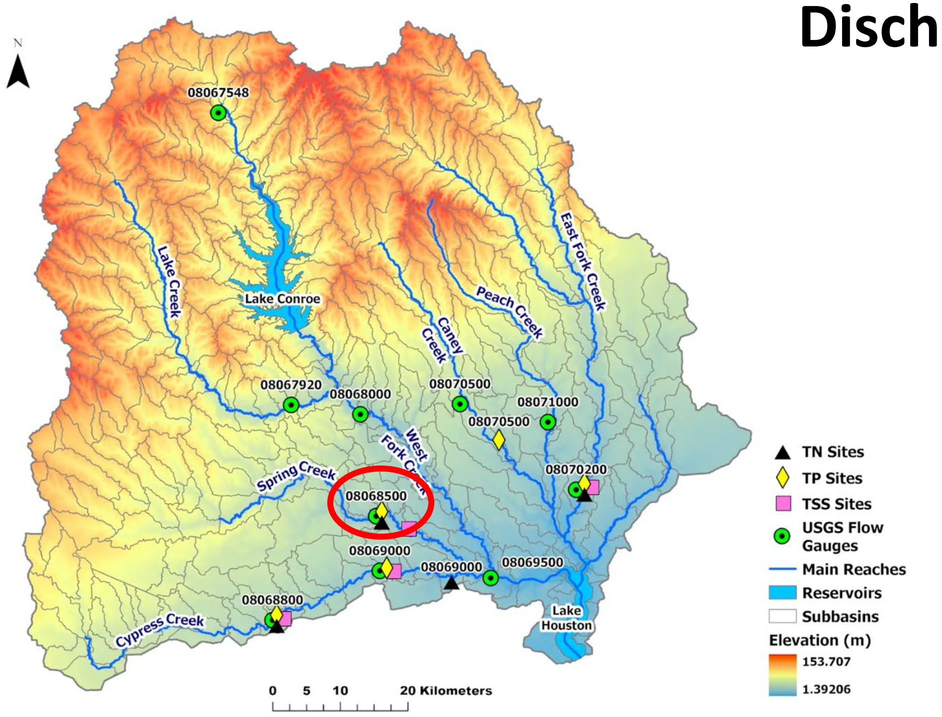
U.S. DEPARTMENT OF AGRICULTURE (USDA)

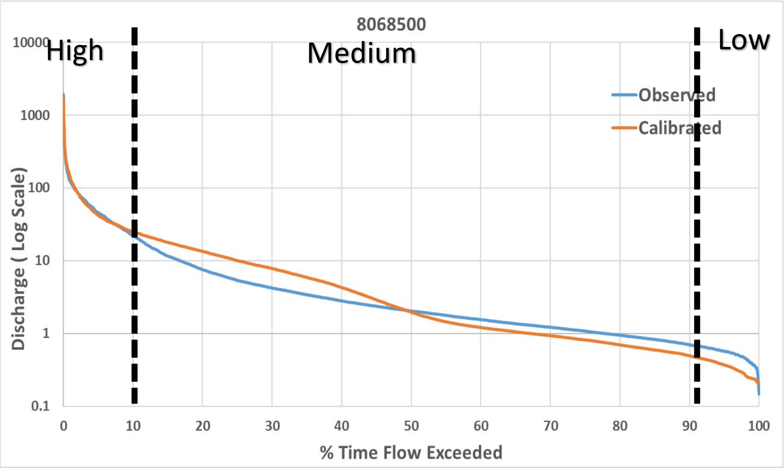
SSPs (**Shared Socioeconomic Pathway**)
GCM (**General Circulation Models)**

Results

Calibration Results → Water Balance → Scenarios

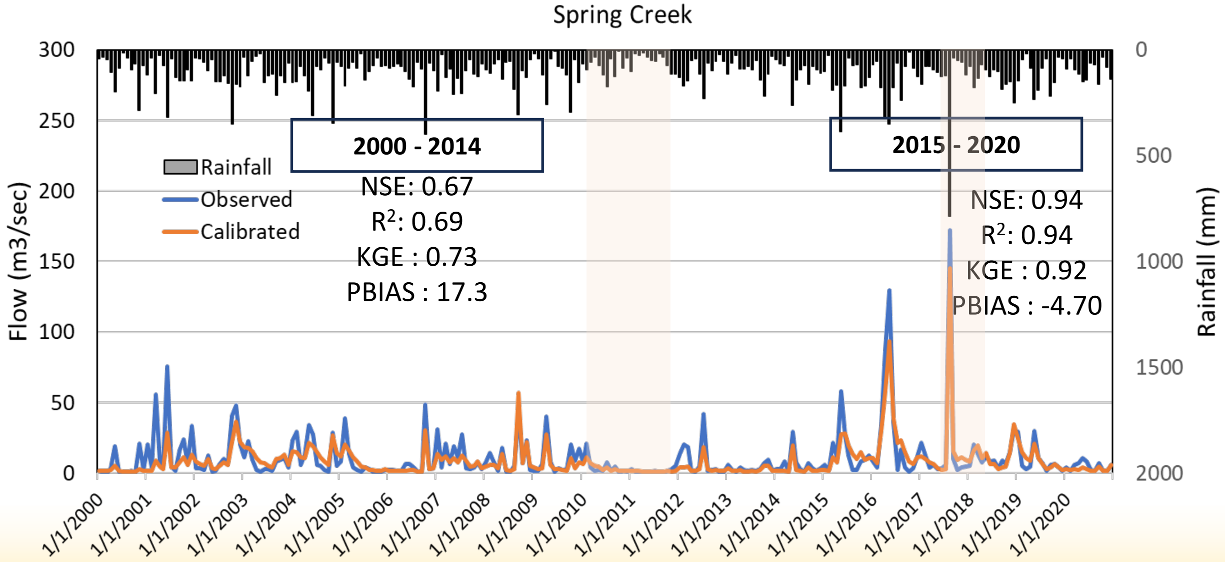
Discharge





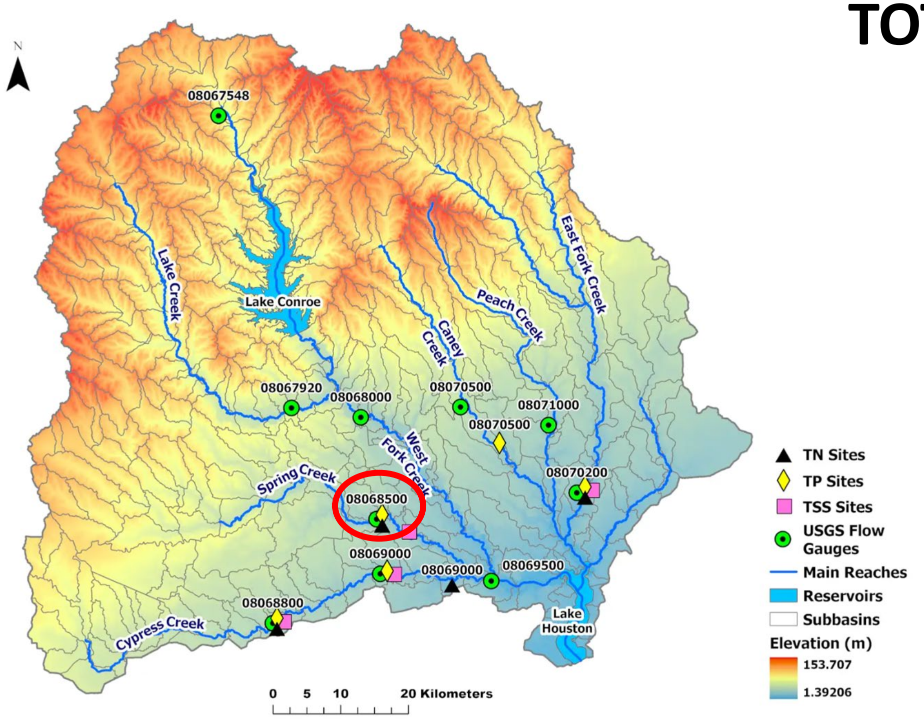
2000 - 2020

Location (Gauge Number)	NSE	PBIAS	KGE	R^2
Upstream of Conroe (08067548)	0.90	-20.8	0.78	0.91
Downstream of Cypress Creek (08069000)	0.82	22.5	0.70	0.90
Downstream of East Fork Creek (08070200)	0.83	9.1	0.75	0.85
Downstream of Spring Creek (08068500)	0.85	8.5	0.87	0.86
Upstream to lake Huston (08069500)	0.82	24.7	0.69	0.88



Results

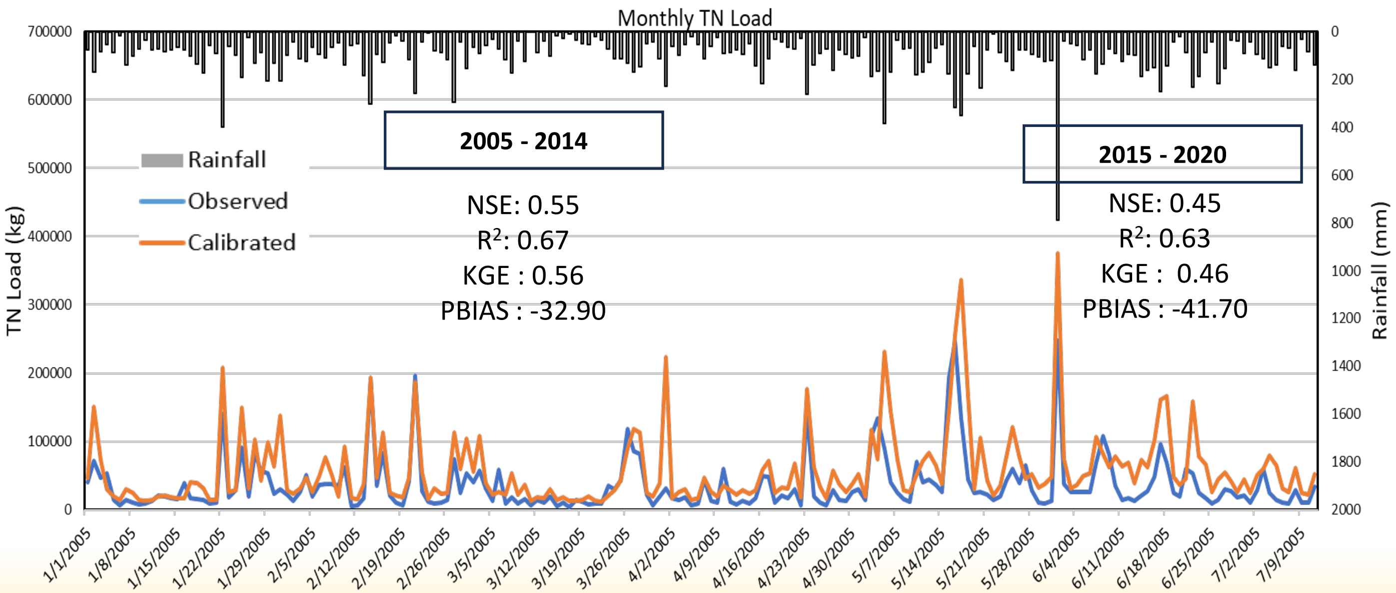
Calibration Results → Water Balance → Scenarios



TOT N

2000 - 2020

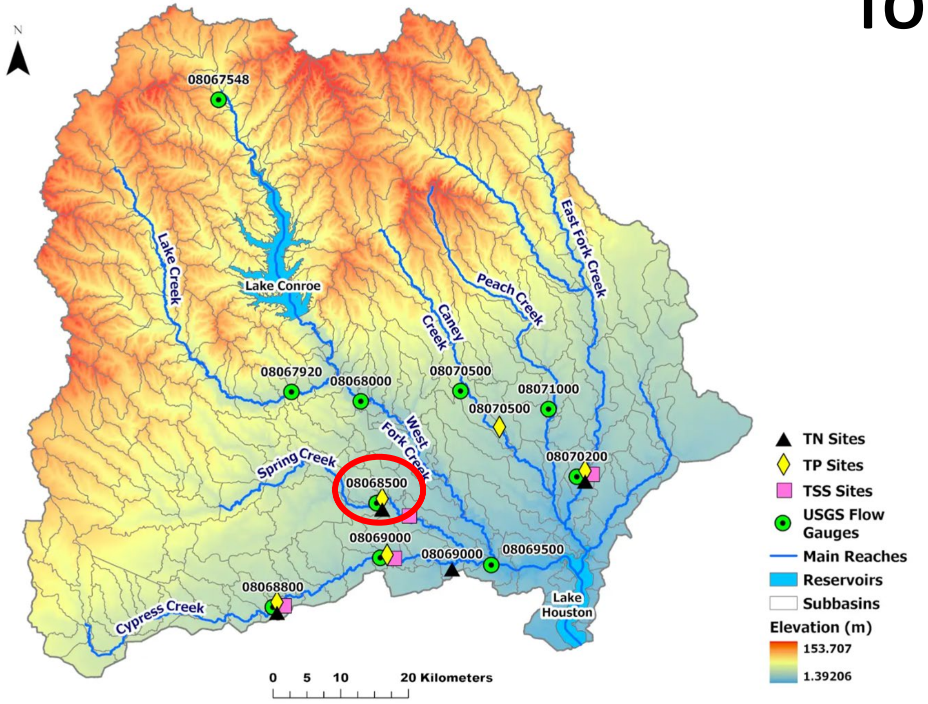
Location	NSE	PBIAS	KGE	R^2
Downstream of Cypress Creek (08069000)	0.82	22.5	0.70	0.90
Downstream of East Fork Creek (08070200)	0.55	21.5	0.53	0.58
Downstream of Spring Creek (08068500)	0.49	-30.6	0.53	0.65



Results

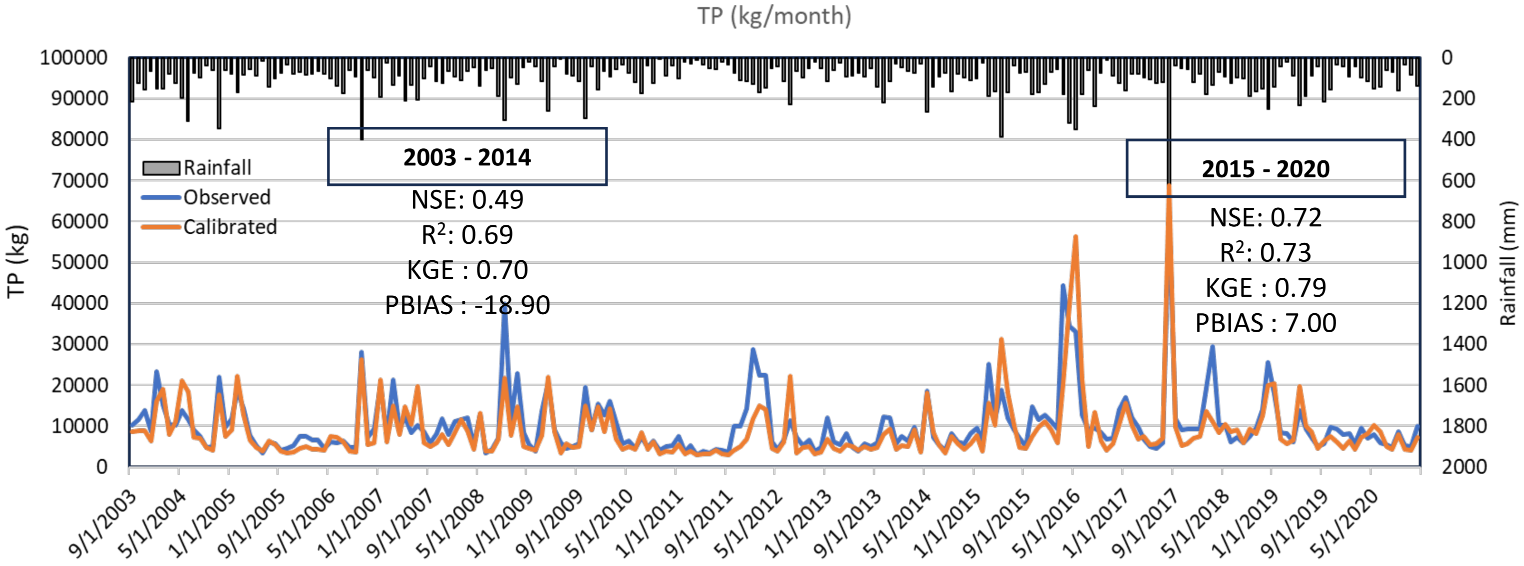
Calibration Results → Water Balance → Scenarios

TOT P



2000 - 2020

Location	NSE	PBIAS	KGE	R^2
Downstream of Cypress Creek (08069000)	0.77	8.6	0.82	0.83
Downstream of East Fork Creek (08070200)	0.50	-0.9	0.60	0.50
Downstream of Spring Creek (08068500)	0.67	-13.80	0.75	0.71



- In comparison to TOT N ,TOT P is well calibrated for spring creek and other gauges

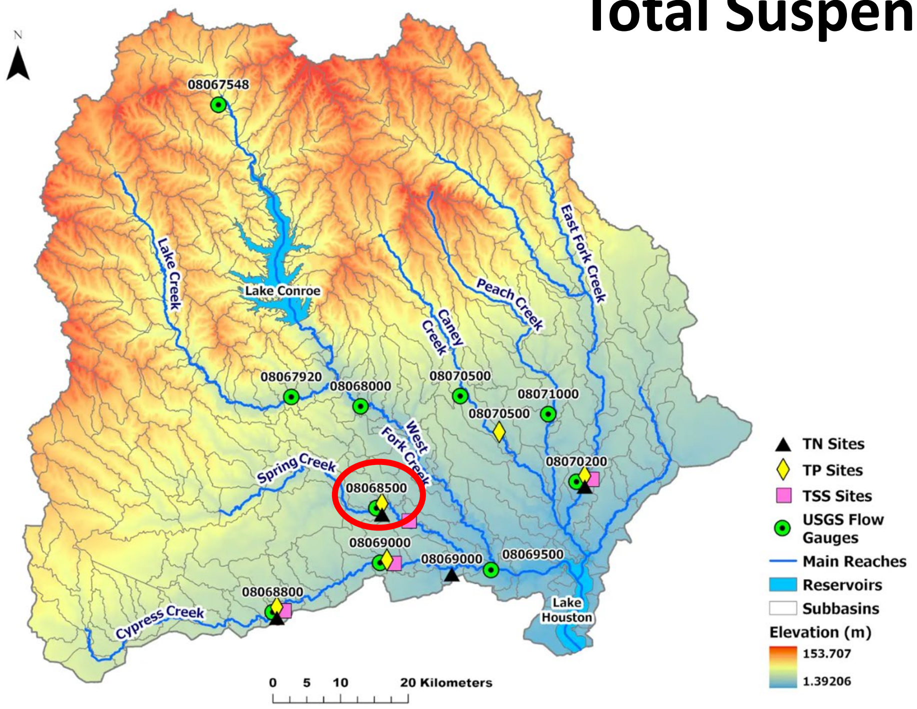
Results

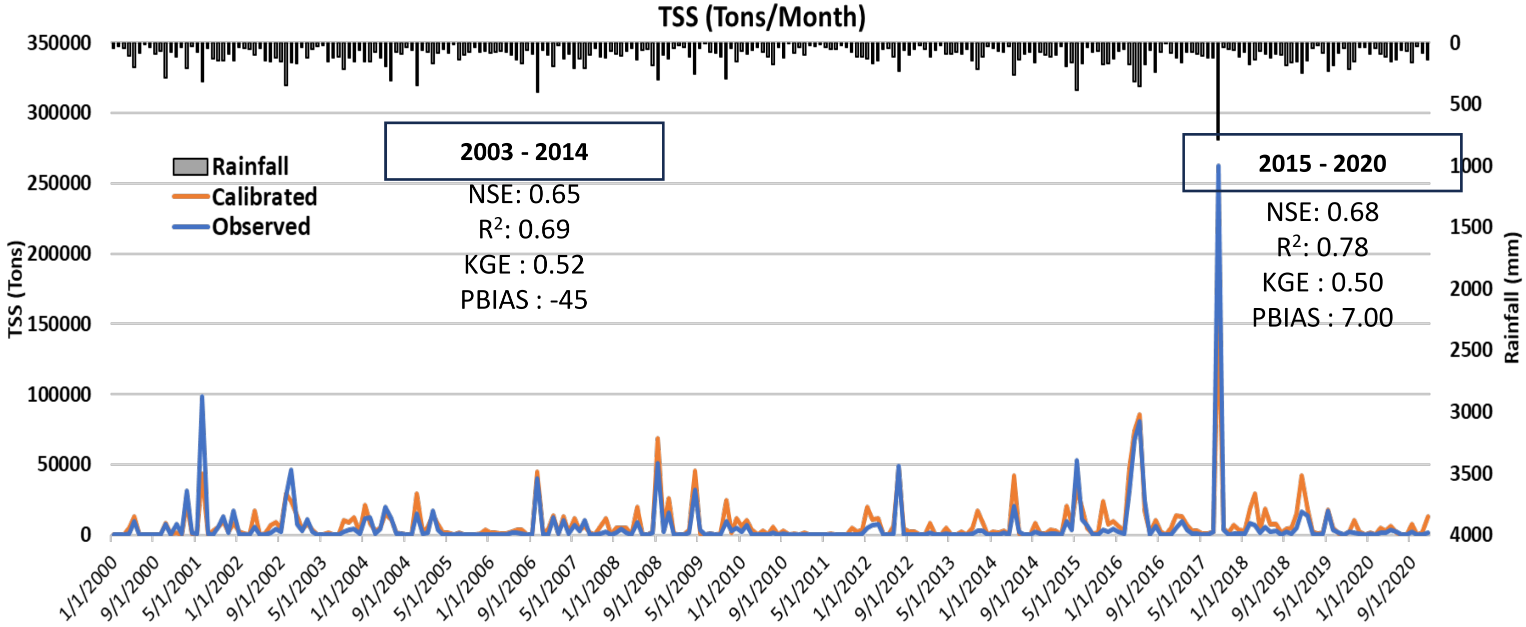
Calibration Results → Water Balance → Scenarios

Total Suspended Sediment

2000 - 2020

Location	NSE	PBIAS	KGE	R^2
Downstream of Cypress Creek (08069000)	0.73	17.5	0.59	0.80
Downstream of East Fork Creek (08070200)	0.66	23.2	0.64	0.67
Downstream of Spring Creek (08068500)	0.68	-20	0.52	0.76

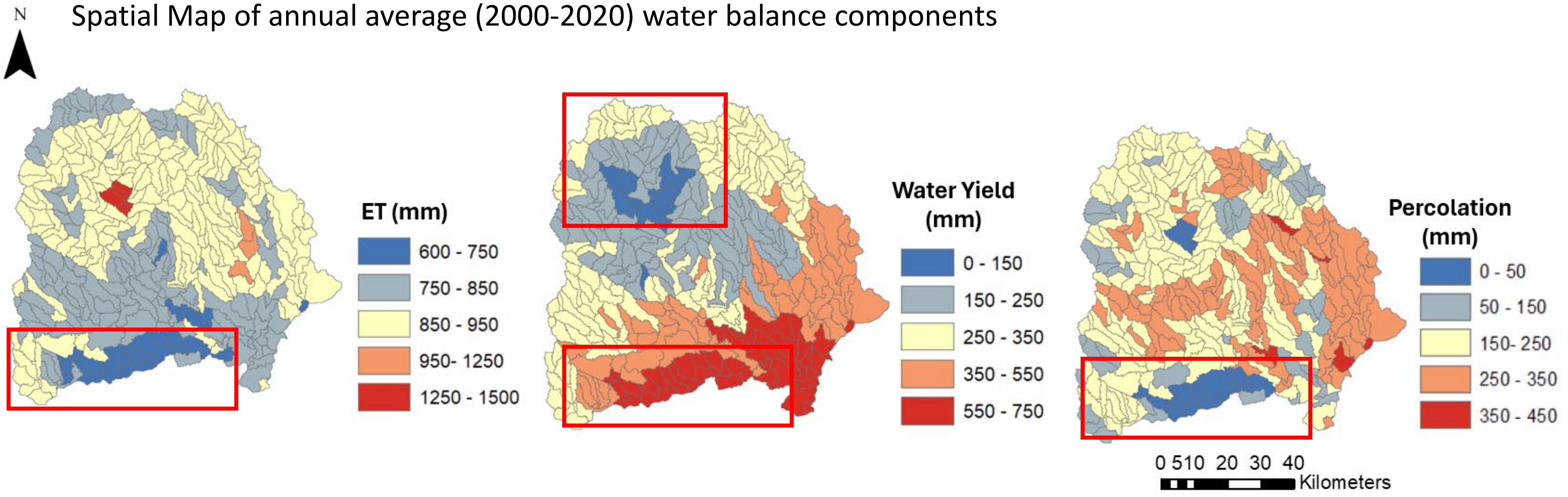




Results

Calibration Results → **Water Balance** → Scenarios

Spatial Map of annual average (2000-2020) water balance components

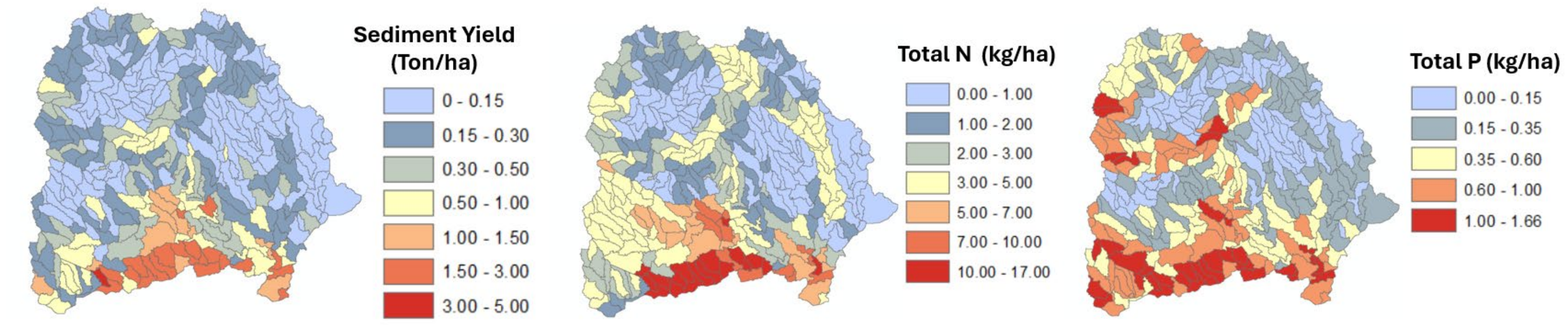


- The simulated water balance components were related to land use distribution.
- Urban-dominated sub-basins of Cypress Creek exhibited the highest water yield, and lowest ET and percolation.
- Upstream sub-basins of Lake Conroe simulated lowest water yield.

Results

Calibration Results → **Water Balance** → Scenarios

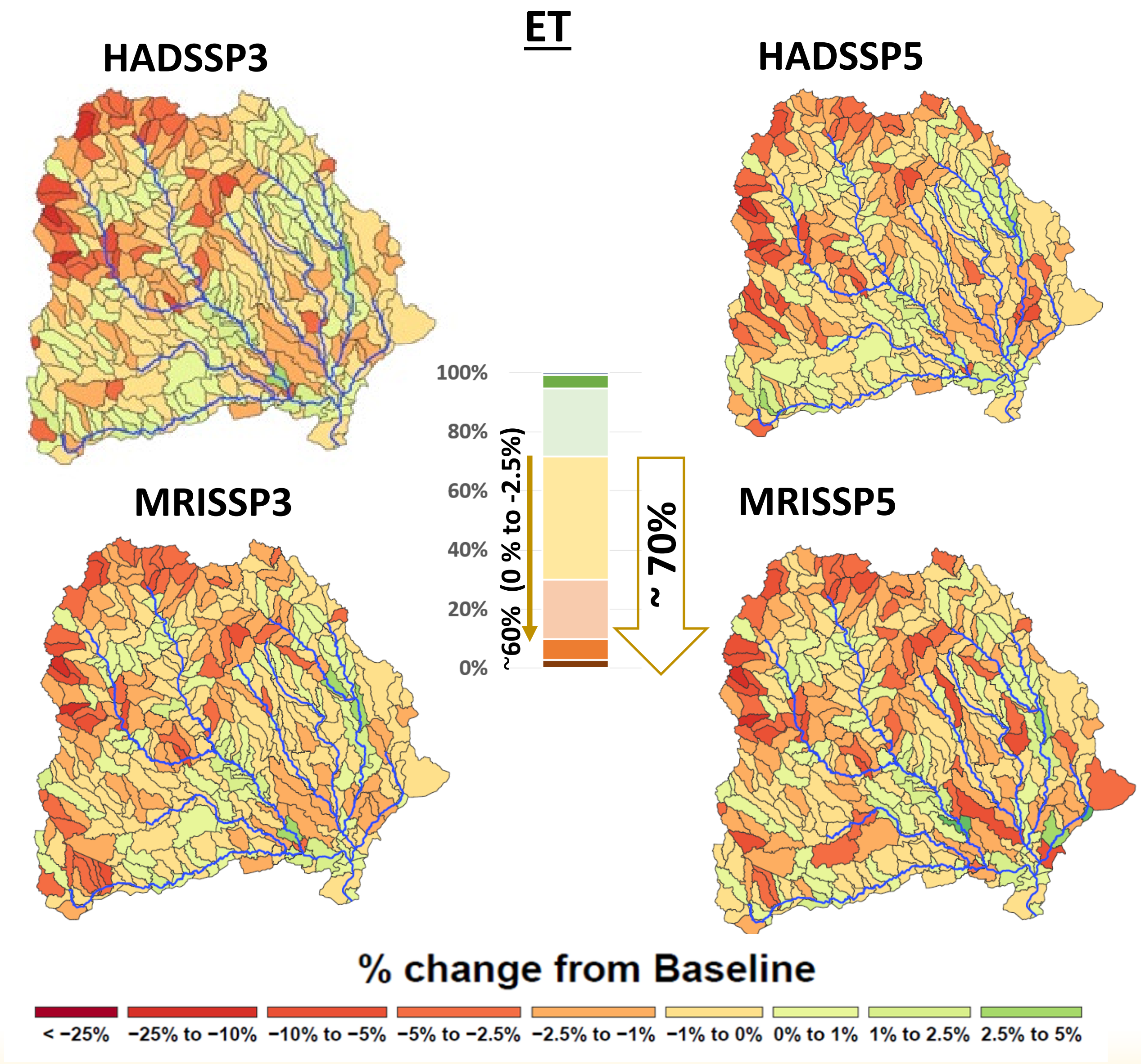
Spatial Map of annual average (2000-2020) nutrient and sediment load

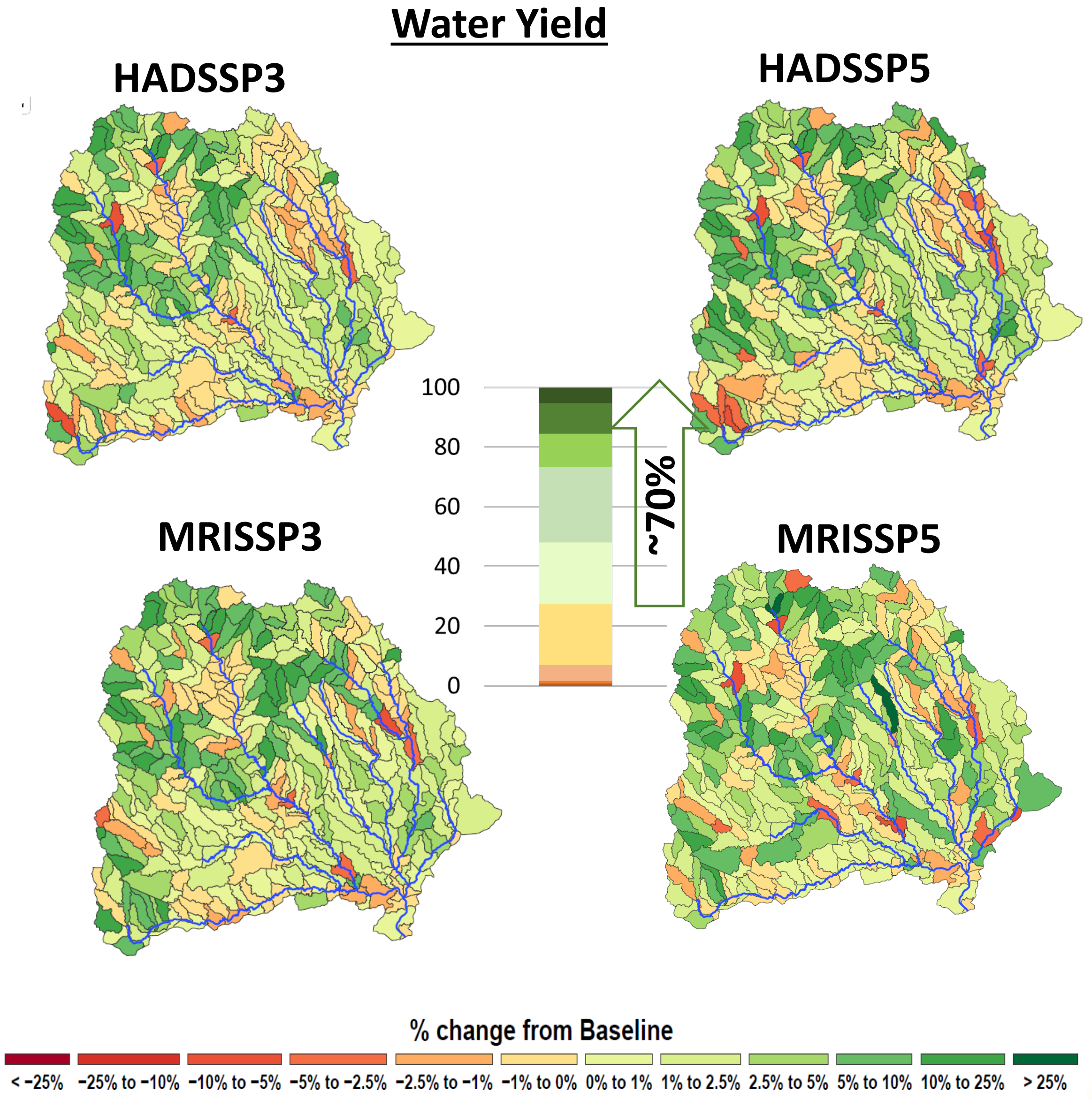


- Similarly , highest sediment and nutrient loads were simulated for Cypress creek sub watersheds due to point sources.
- Apart from cypress creek, vicinity of Lake Conroe also exhibited high TP load due to point sources.

Results

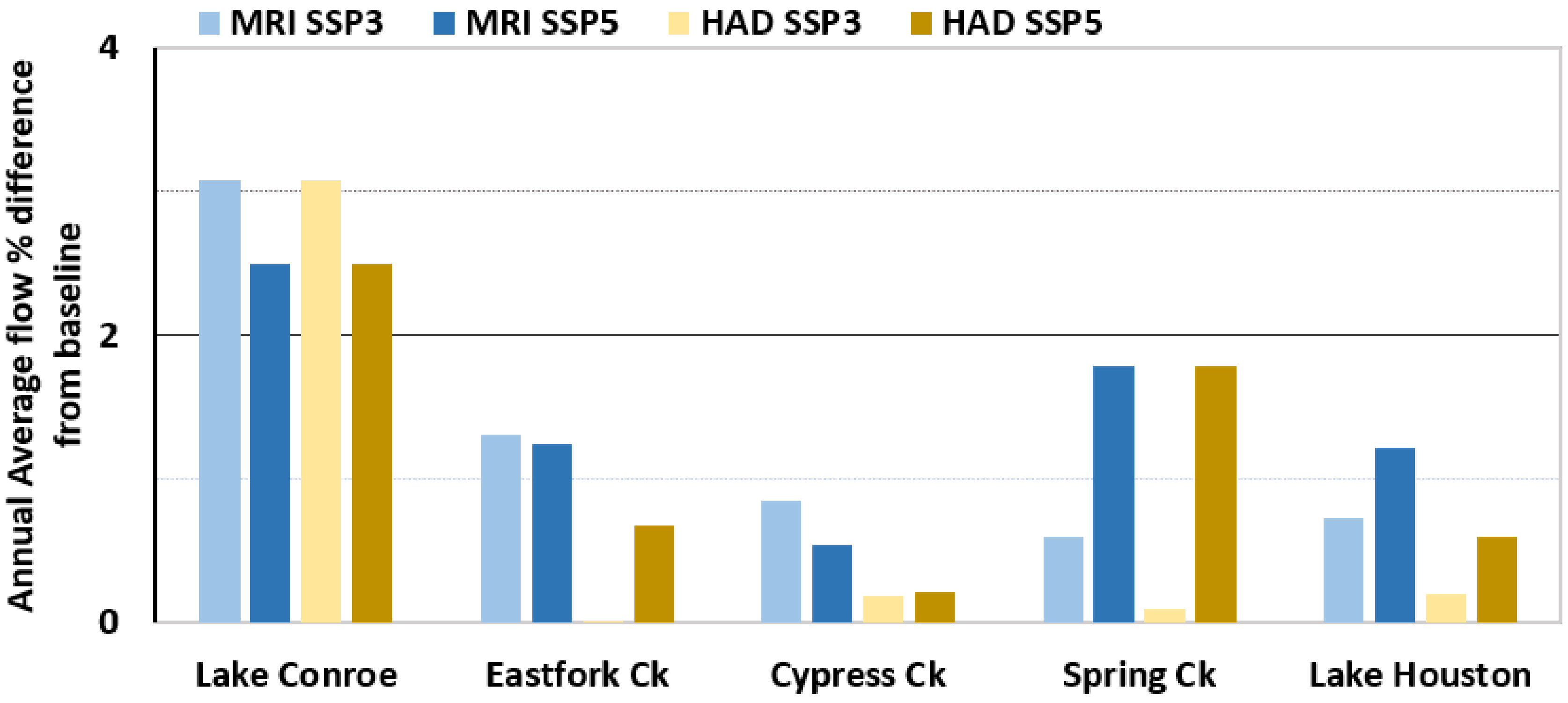
Calibration Results → Water Balance → Scenarios (Projected Land use)





Results

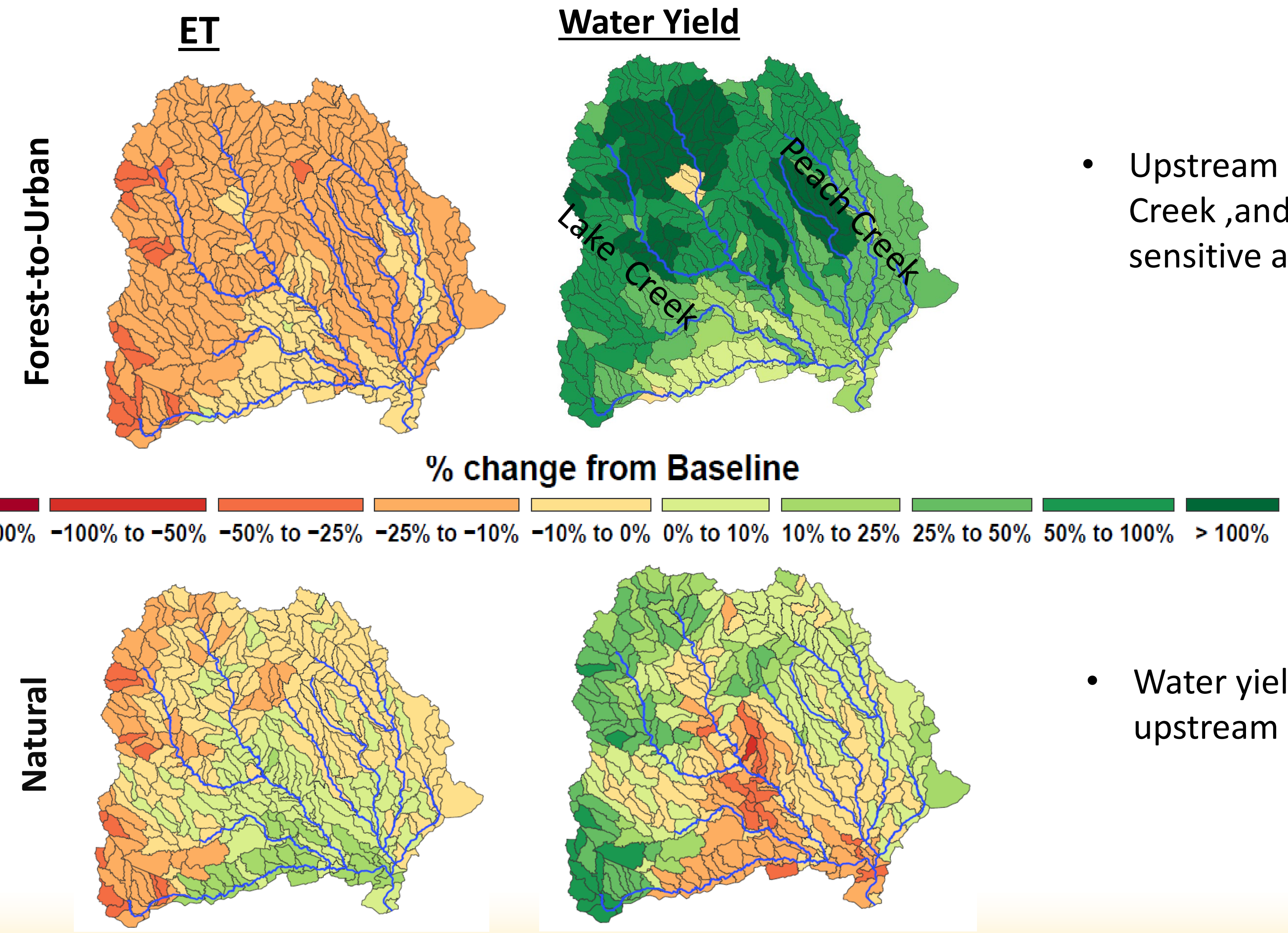
Calibration Results → Water Balance → Scenarios (streamflow)



- Steam flow consistently increases from baseline across all projections for each tributary.
- Land use projections have relatively more impact on the inflow to Lake Conroe compared to other tributaries.
- The effect of land use change at the watershed outlet is minimal, within 1%.
- Hot climate and Low population growth scenario (HAD SSP3) has negligible impact in the tributaries.

Results

Calibration Results → Water Balance → Scenarios (Extreme Scenario)



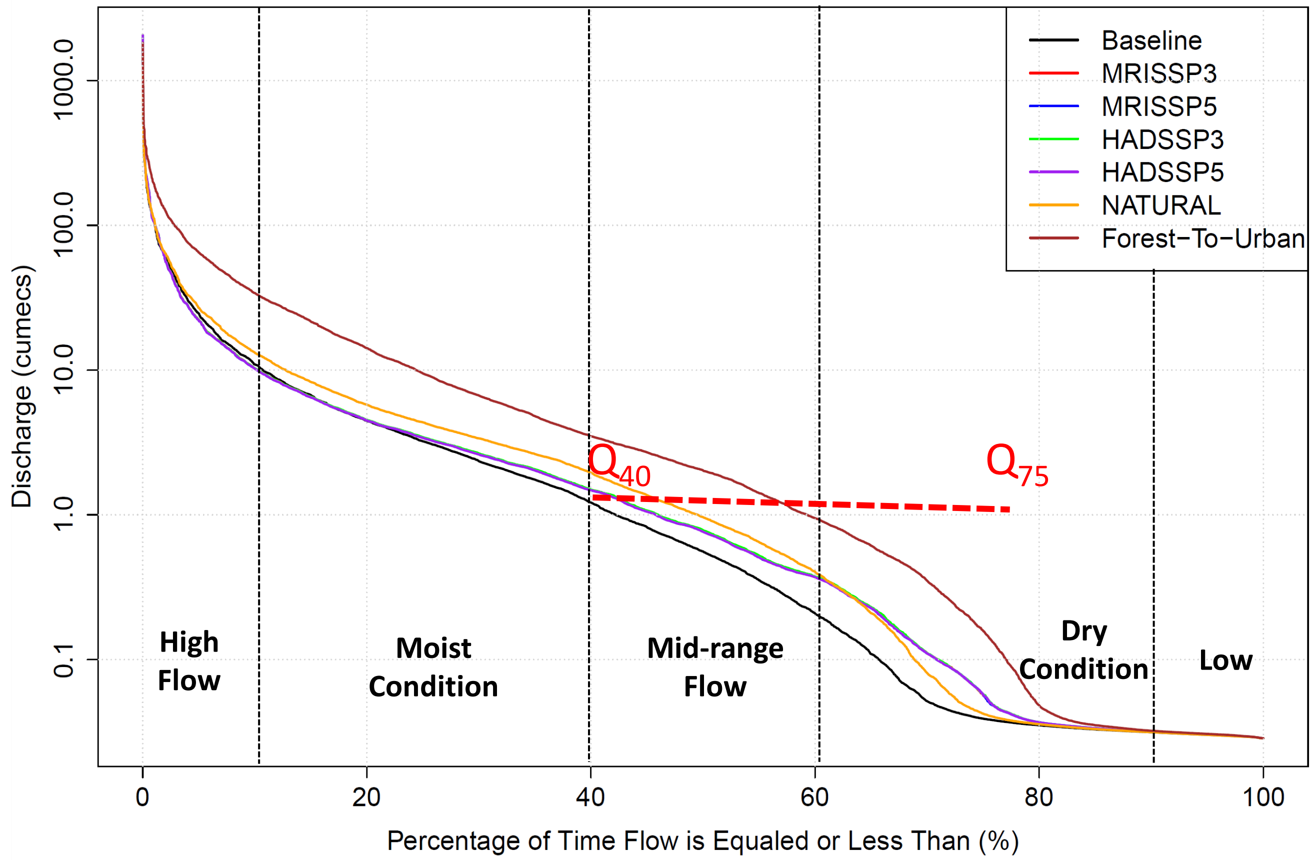
- Upstream region of Lake Conroe , Peach Creek ,and Lake Creek are the most sensitive areas.

- Water yield decreases by 10-25 % in the upstream subbasins to Lake Huston

Results

Calibration Results → Water Balance → Scenarios (FDC)

Lake Conroe

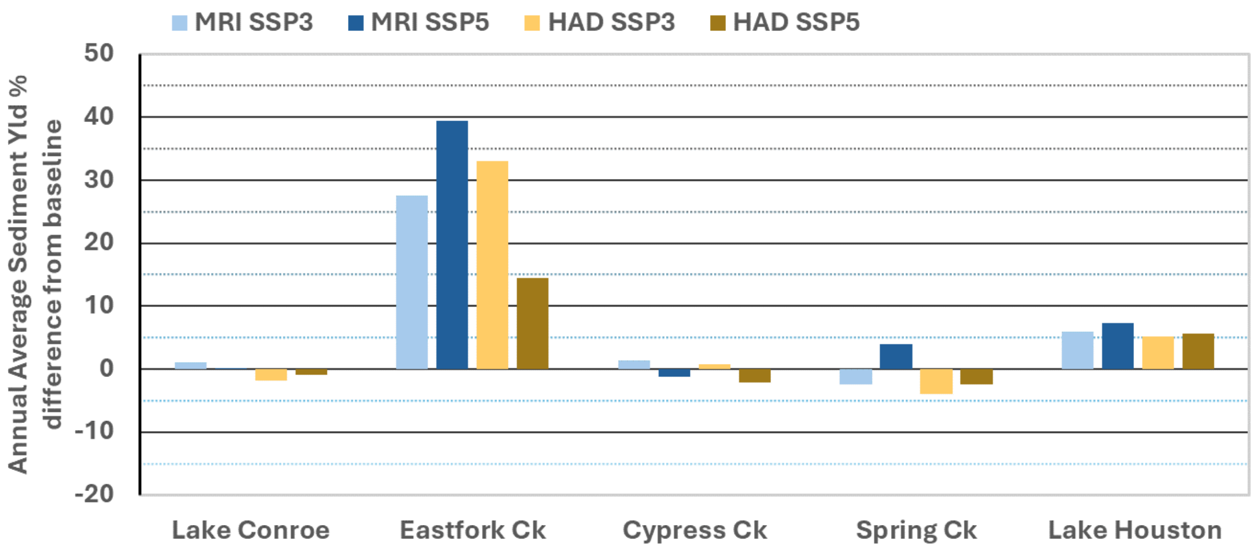


Flow regime classifications based on EPA standards

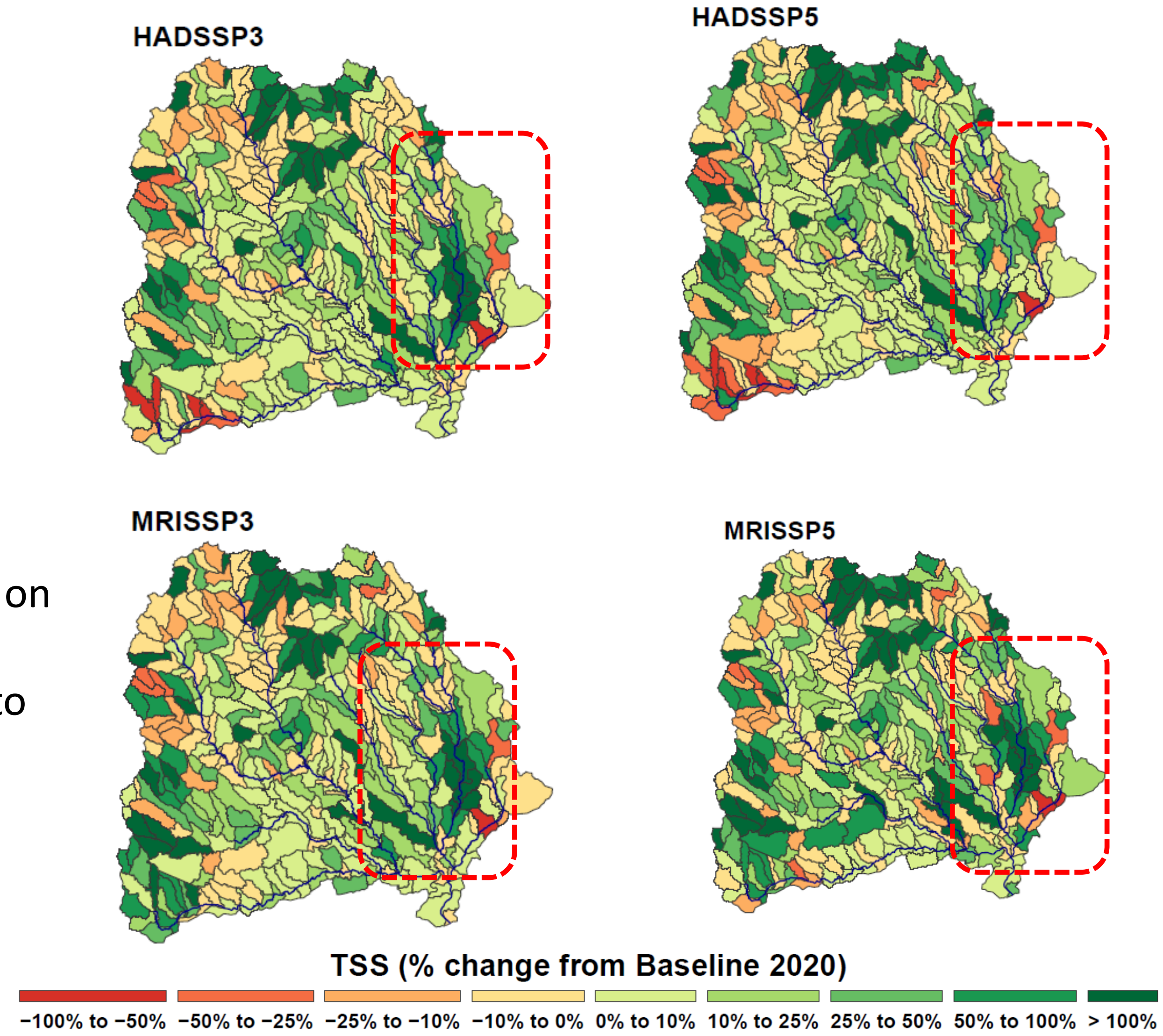
- The flow durations for different land use projections are quite similar.
- Mid-range and dry condition flows highly impacted due to land use projections.
- Q_{50} increased from 0.56 to 0.78 m3/sec

Results

Calibration Results → Water Balance → Scenarios (Sediment Load)



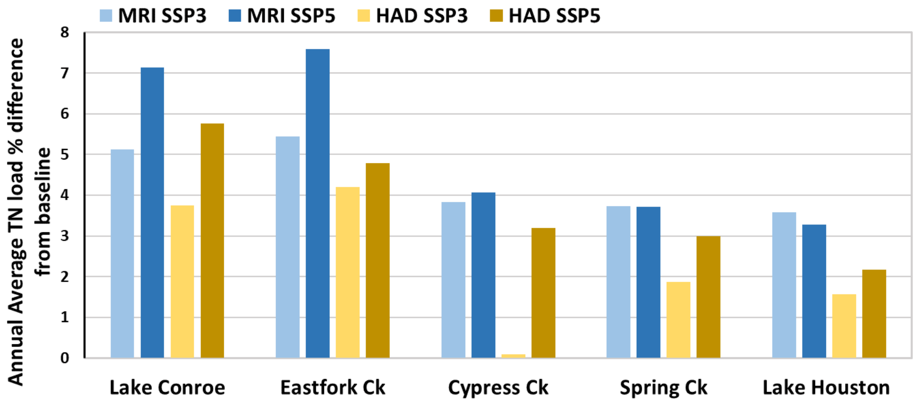
- East Fork creek showed a strong response to land use change on sediment yield
- Simulations showed that the Eastern region is more sensitive to sediment load across all projections.

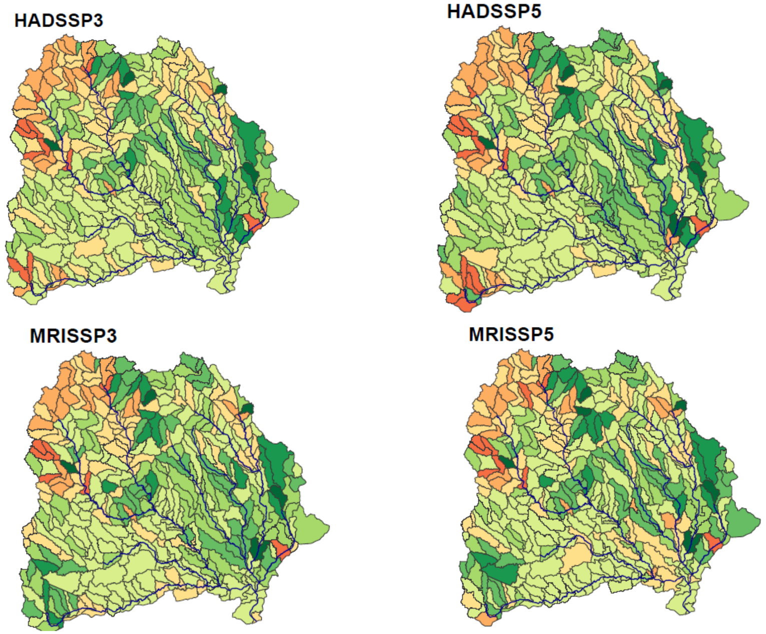


Results

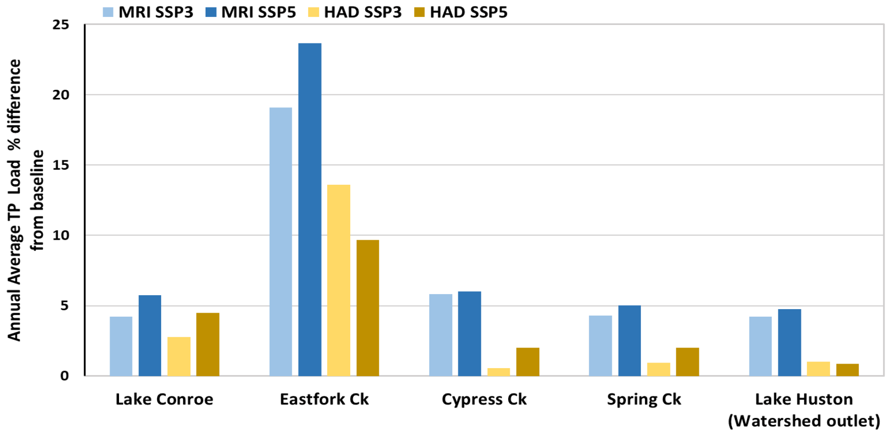
Calibration Results → Water Balance → **Scenarios (Nutrient Load)**

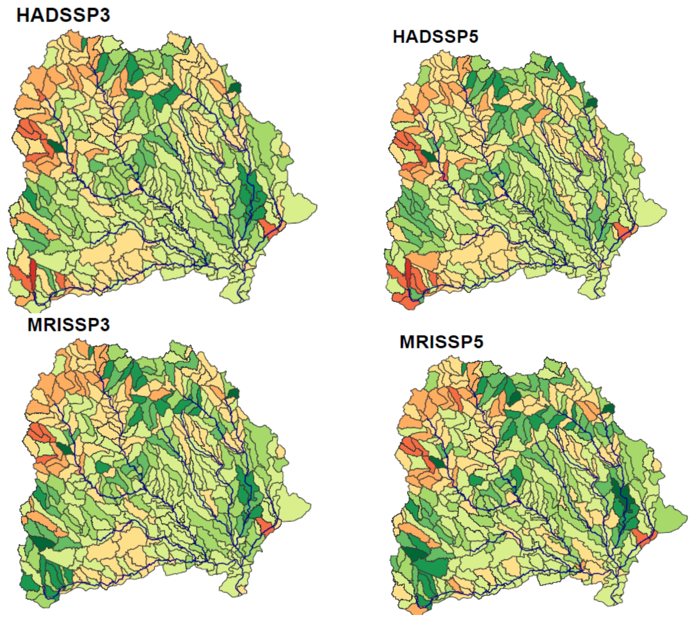
TN



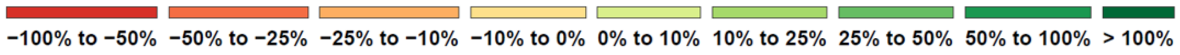


TP



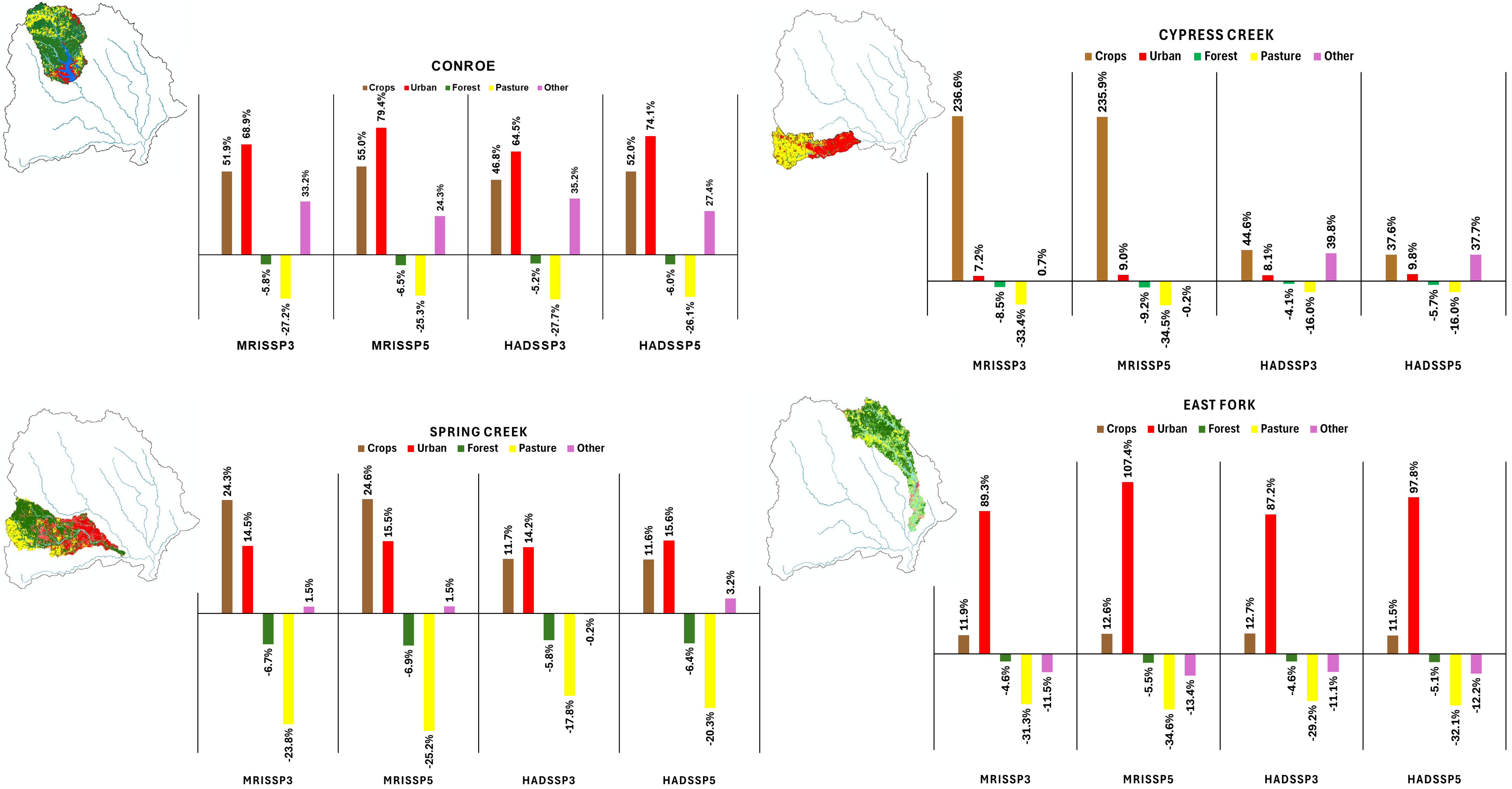


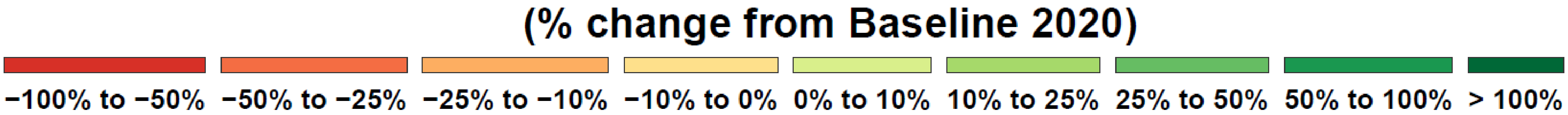
(% change from Baseline 2020)



Summary

- A 4% increase in urban land use for entire watershed can significantly alter watershed hydrology, raising water yield by over 10% in the upstream region of watershed (Lake Conroe's upstream sub-basins)
- Deforestation in the East fork region can rise excessively high sediment load (15% - 40%).
- Balanced land use planning is essential for effective water resource management and flood mitigation.


CONROE
Crops Urban Forest Pasture Other
51.9% 68.9% -5.8% -27.2% 33.2%
55.0% 79.4% -6.5% -25.3% 24.3%
46.8% 64.5% -5.2% -27.7% 35.2%
52.0% 74.1% -6.0% -26.1% 27.4%
MRISSP3 MRISSP5 HADSSP3 HADSSP5
CYPRESS CREEK
Crops Urban Forest Pasture Other
236.6% 7.2% -8.5% -33.4% 0.7%
235.9% 9.0% -9.2% -34.5% -0.2%
44.6% 8.1% -4.1% -16.0% 39.8%
37.6% 9.8% -5.7% -16.0% 37.7%
MRISSP3 MRISSP5 HADSSP3 HADSSP5
SPRING CREEK
Crops Urban Forest Pasture Other
24.3% 14.5% -6.7% -23.8% 1.5%
24.6% 15.5% -6.9% -25.2% 1.5%
11.7% 14.2% -5.8% -17.8% -0.2%
11.6% 15.6% -6.4% -20.3% 3.2%
MRISSP3 MRISSP5 HADSSP3 HADSSP5
EAST FORK
Crops Urban Forest Pasture Other
11.9% 89.3% -4.6% -31.3% -11.5%
12.6% 107.4% -5.5% -34.6% -13.4%
12.7% 87.2% -4.6% -29.2% -11.1%
11.5% 97.8% -5.1% -32.1% -12.2%
MRISSP3 MRISSP5 HADSSP3 HADSSP5


(% change from Baseline 2020)
−100% to −50%
−50% to −25%
−25% to −10%
−10% to 0%
0% to 10%
10% to 25%
25% to 50%
50% to 100%
> 100%