Updating Soil Hydraulic Properties under Changing Land Use/Cover for Improved Hydrologic Prediction

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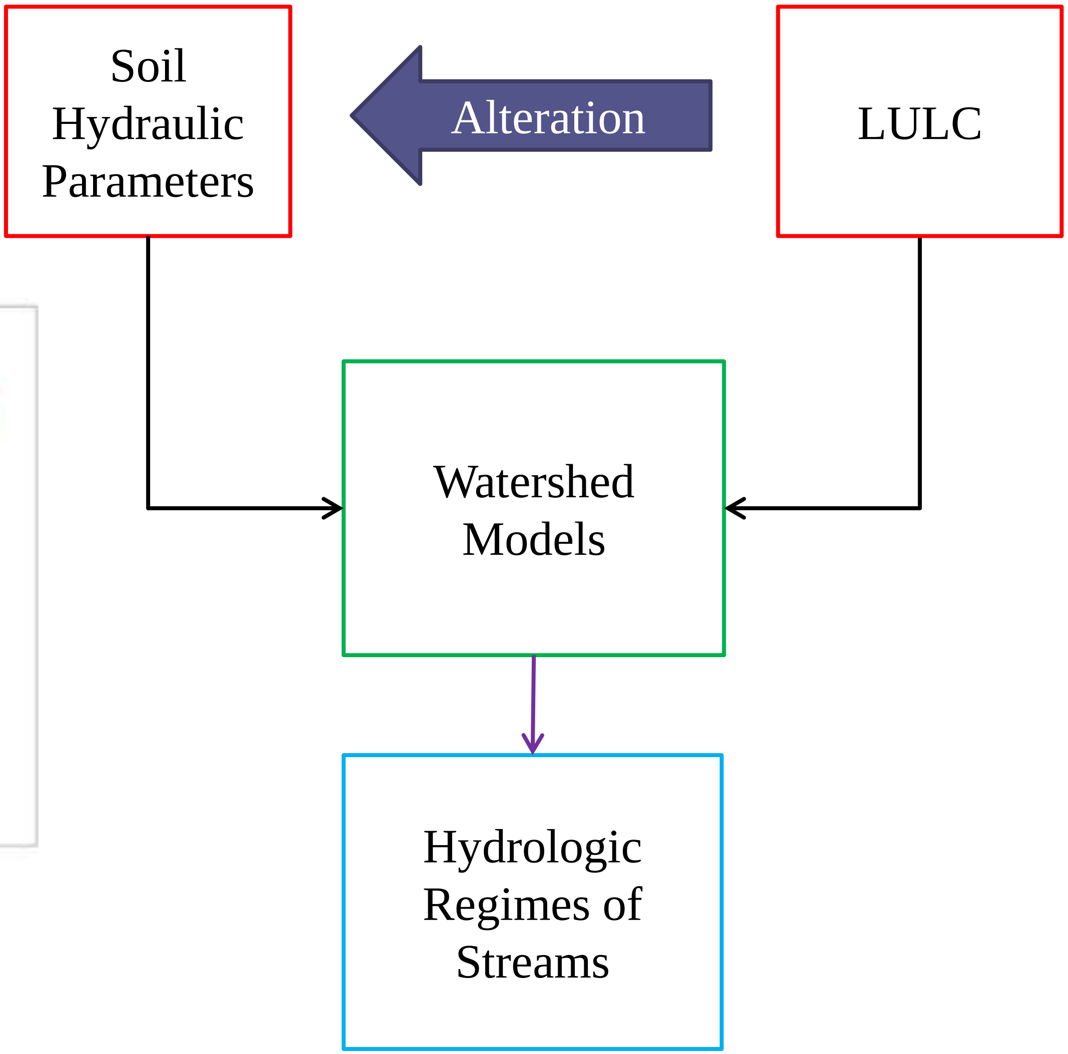
Introduction

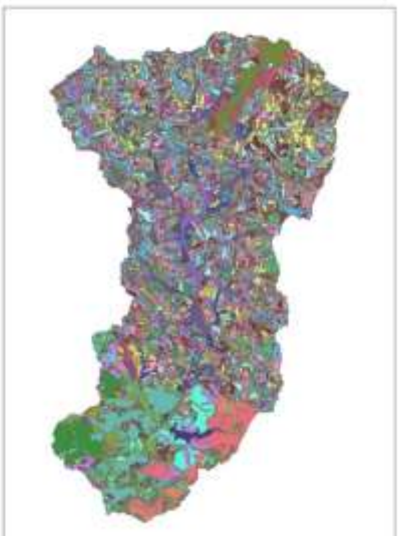
- Land use/cover (LULC) change impacts hydrology.
- LULC change may affect soil properties.
  - ✓ hydraulic conductivity, bulk density, porosity etc.
- Hydrology is function of soil characteristics
- There is a lack of understanding of how to quantify the changes in soil hydraulic properties under changing LULC.

Introduction

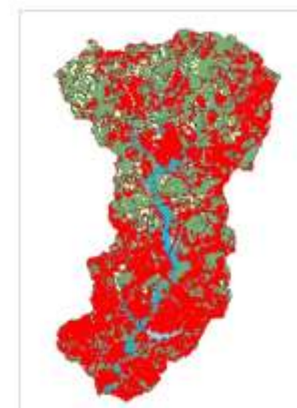
1992 LULC



Soil Data

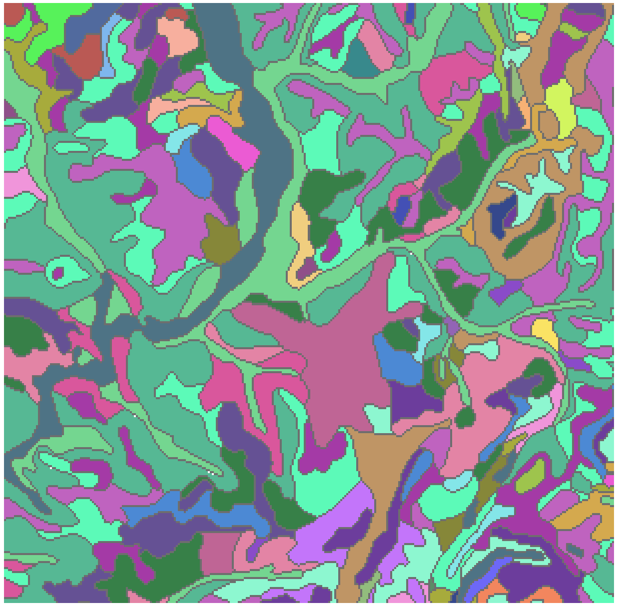


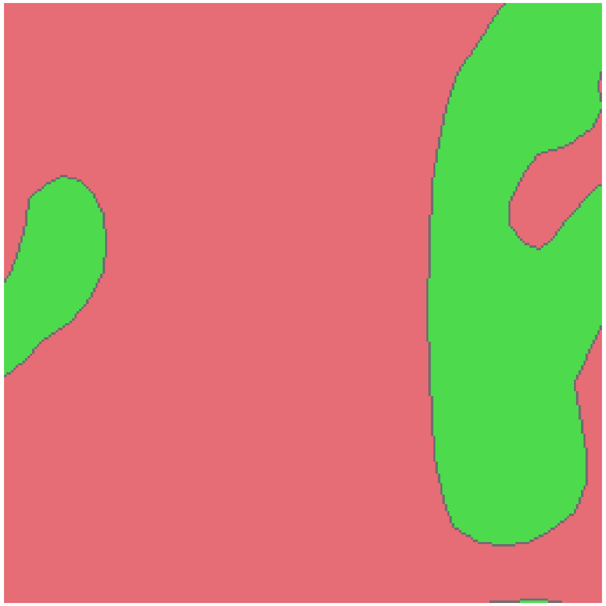
2011 LULC



Soil Survey Geographic Dataset (SSURGO)

A) SSURGO and B) STATSGO data sets

A) 

B) 

- ✓ SSURGO is still under development and does not cover the entire United States.
- ✓ Most existing studies only focus on soil data extraction from SSURGO (Peschel et al., 2003, 2006; Sheshukov et al., 2009); however, the validity of actual soil hydraulic parameters and the others are not sufficiently examined beforehand.

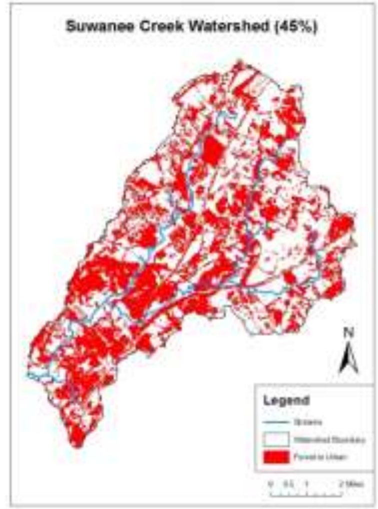
Problem Statement

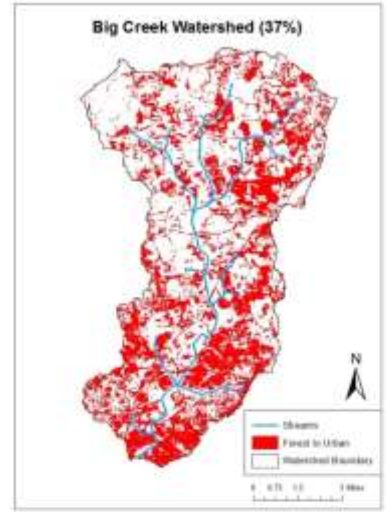
- Most studies analyze the effect of land use change on the watershed flow without considering the change in soil parameters due to land use land cover change.
- LULC may induce an alteration in other associated landscape characteristics such as soil properties.
- For hydrologic modelling, rapid but robust methods for hydraulic conductivity prediction are still needed, where in-situ measurements may not be practical.
- Indirect methods for hydraulic conductivity prediction, which involve pedotransfer functions (PTFs), can potentially address the solution.

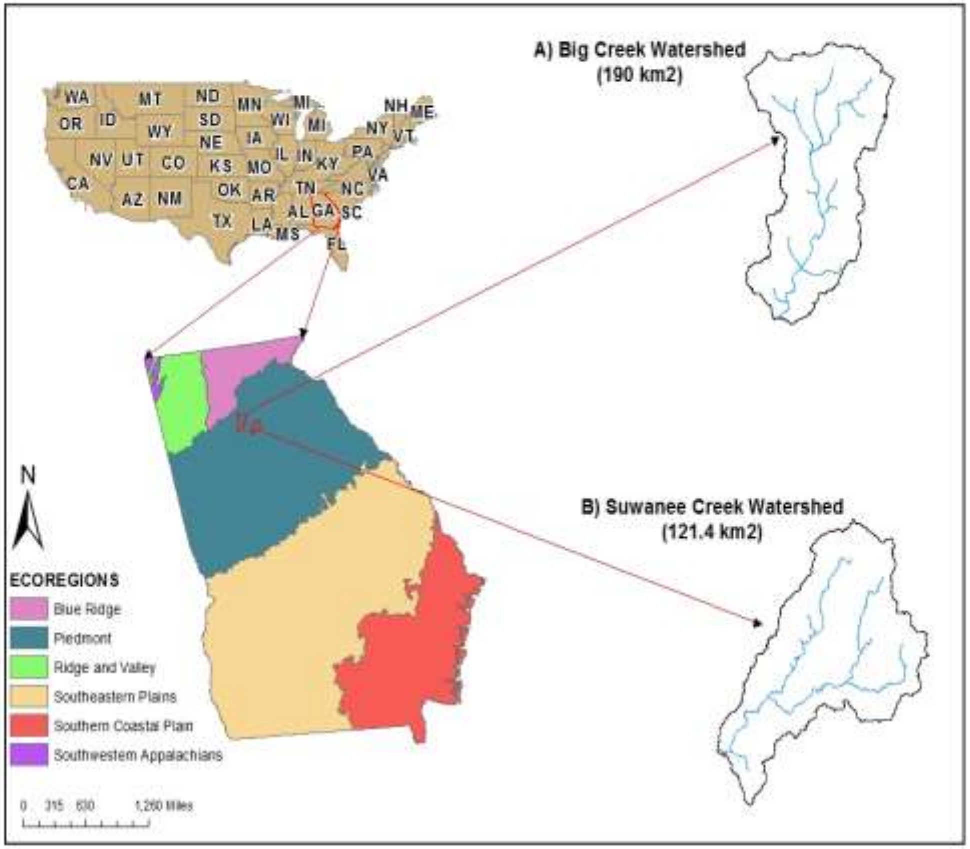
OBJECTIVES

- Update certain soil hydraulic parameters using PTFs under LULC change.
- Assess the applicability of this approach in two watersheds in Northwest Georgia with the Soil and Water Assessment Tool (SWAT).

STUDY AREA

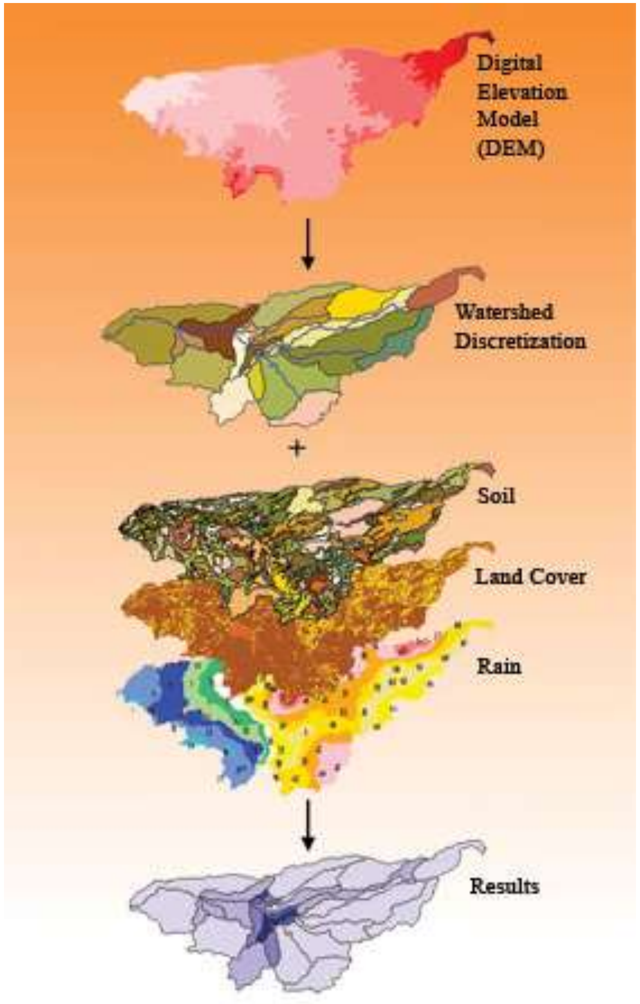






Stream Flow Gauging Station Name	Suwanee Creek	Big Creek
USGS Station Number	2334885	2335700
Drainage Area (km²)	121.4	190.0
Period of Record	1985-2013	1985-2013
1992 -2011 LULC (%) Forest to Urban	45.4	37.1

Soil and Water Assessment Tool (SWAT)



SWAT is a river basin scale model developed to quantify the impacts of land management practices in large, complex watersheds.

Model Inputs

- ✓ Climatic Inputs (Daily Precipitation, Max & Min Temp., Solar Radiation , Relative humidity, and Wind speed)
- ✓ Digital Elevation Map (DEM)
- ✓ Land Use/Cover Map
- ✓ Soil Database (SSURGO or STATSGO)

Model Predictions

- ✓ Flow
- ✓ Sediment
- ✓ Nutrients (Nitrogen and Phosphorus)
- ✓ Pesticide
- ✓ Bacteria

Changes in Soil properties by Land Use Change

- PTFs were used to derive changes in soil hydraulic properties.
- PTF of Rawls and Brakensiek (1985) was used to estimate saturated hydraulic conductivity.
- To quantify new hydraulic conductivity, bulk density, porosity and soil texture were used.

Changes in Soil properties by Land Use Change

- Values for porosity as required in the Rawls and Brakensiek PTF were derived from SSURGO databases (bulk density was updated based on literature).
- From the literature; average change in bulk density associated with forest to urban transition was approximately 30 % increase.

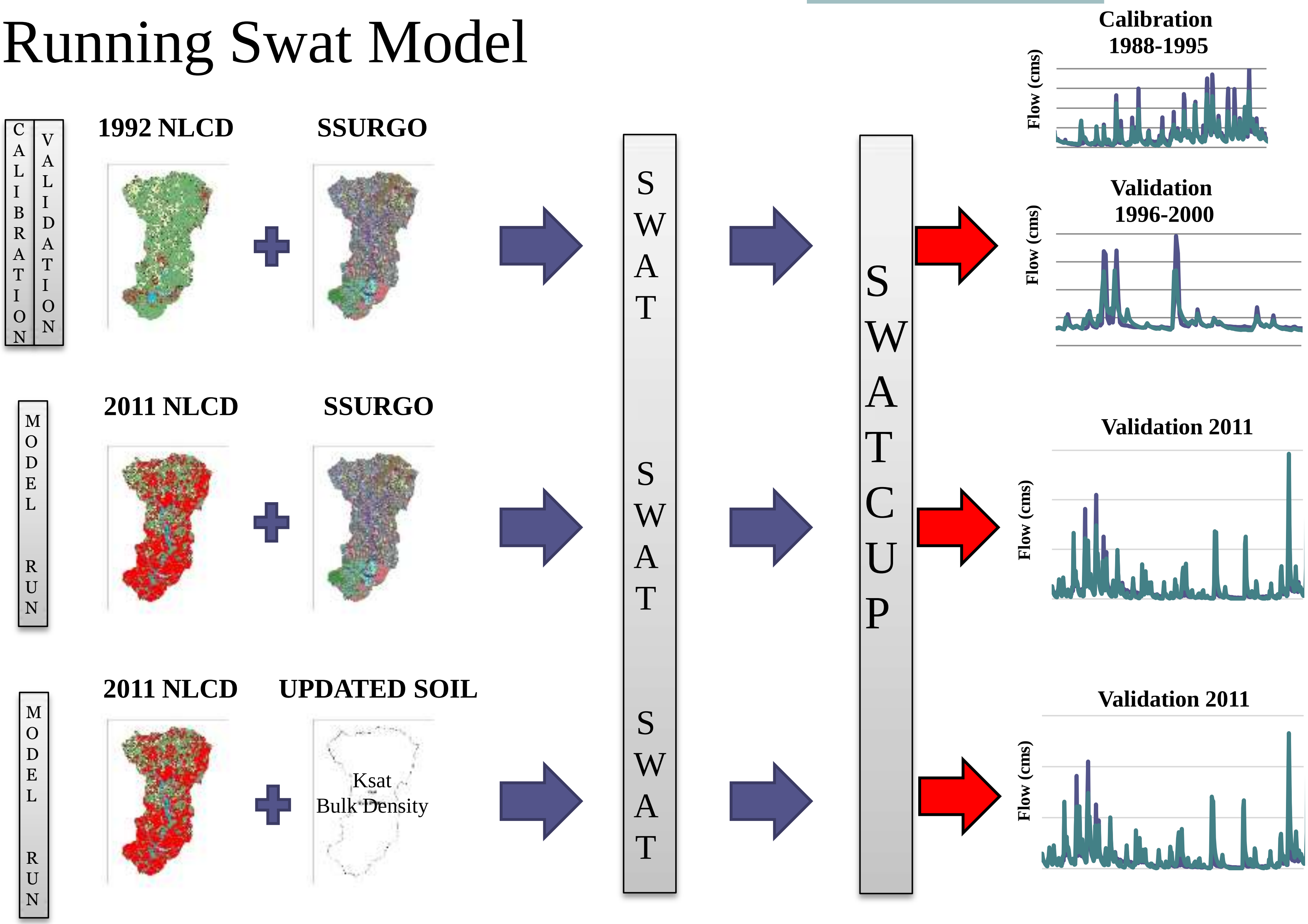
Average Forest Bulk Density = 1.07 g/cm3

Average Urban Bulk Density= 1.38 g/cm3

Model parameters and regression equation used in this study

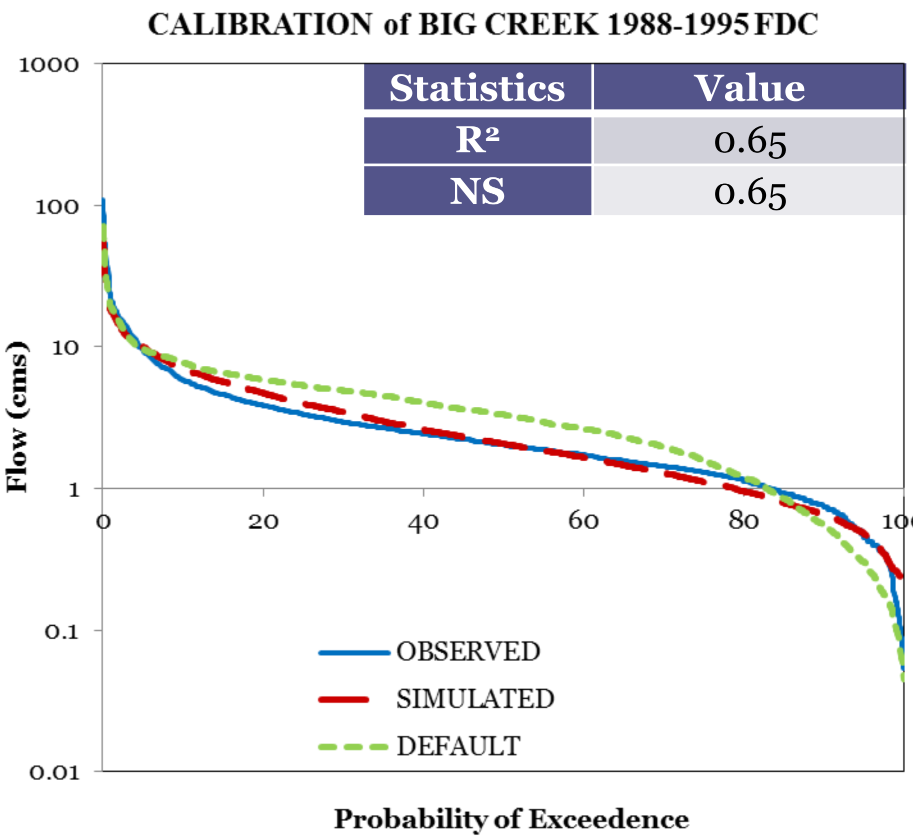
Hydraulic Soil Characteristic	Equations	Parameters
Saturated hydraulic conductivity (Ksat)	Ksat = ln[19.52348ϕ − 8.96847 − 0.028212C + 0.00018107S^2 − 0.0094125C^2 − 8.395215$ϕ^2$ + 0.077718Sϕ − 0.00298$S^2ϕ^2$ − 20.019492$C^2ϕ^2$ + 0.0000173S^2C + 0.02733C^2ϕ + 30.001434S^2ϕ − 0.0000035C^2S]	ϕ: Porosity C: Clay % S: Sand %
Wilting Point (WP)	WP= 0.40*C*p_b^d	C: Percent clay of the layer (%) p_b^d: Dry bulk density (g/cm^3)
Porosity (ϕ)	ϕ=1-p_b^d/ρd	p_b^d: Dry bulk density (g/cm^3) ρd: Particle density (2.65 g/cm^3)
Dry bulk density (p_b^d)	p_b^d = (1-ϕ)*ρd p_b^d = (p_b^w-AWC)/(0.4*C+1)	p_b^w: Wet bulk density ρd: Particle density (2.65 g/cm^3) AWC: Available water content C: Clay %
Wet bulk density (p_b^w)	p_b^w= WP+AWC+(1-ϕ)*2.65	WP: Wilting point AWC: Available water content ϕ: Porosity
Field Capacity (FC)	FC=WP+AWC	WP: Wilting point AWC: Available water content

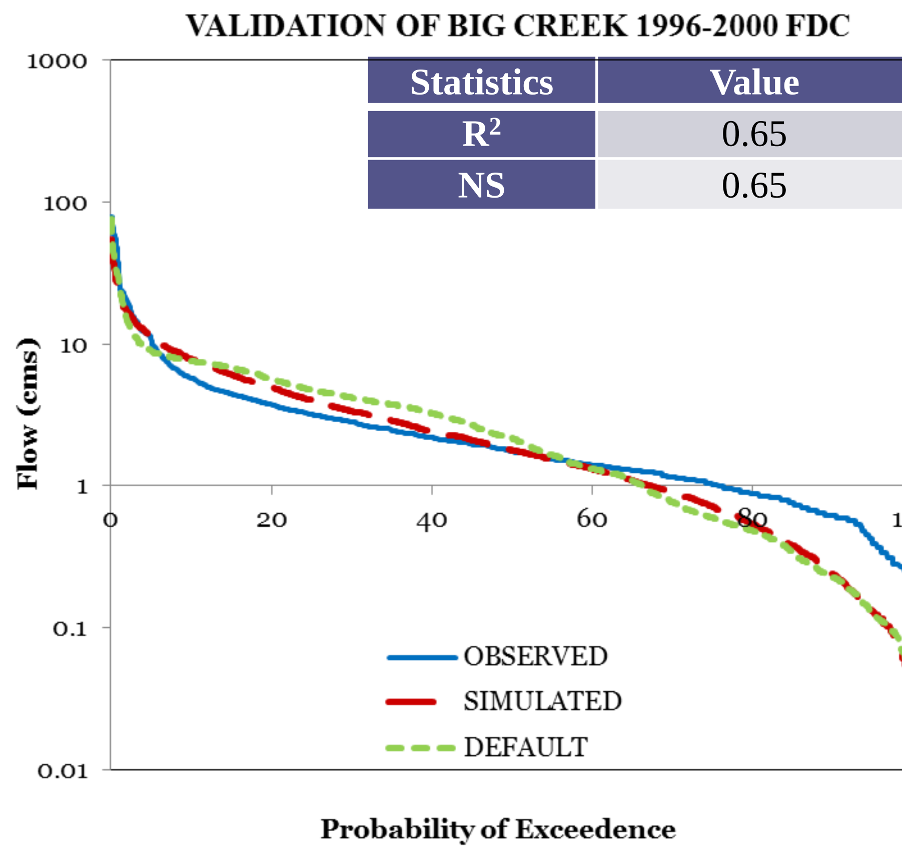
Running Swat Model



RESULTS

- Hydrological calibration and validation result in Big Creek watershed

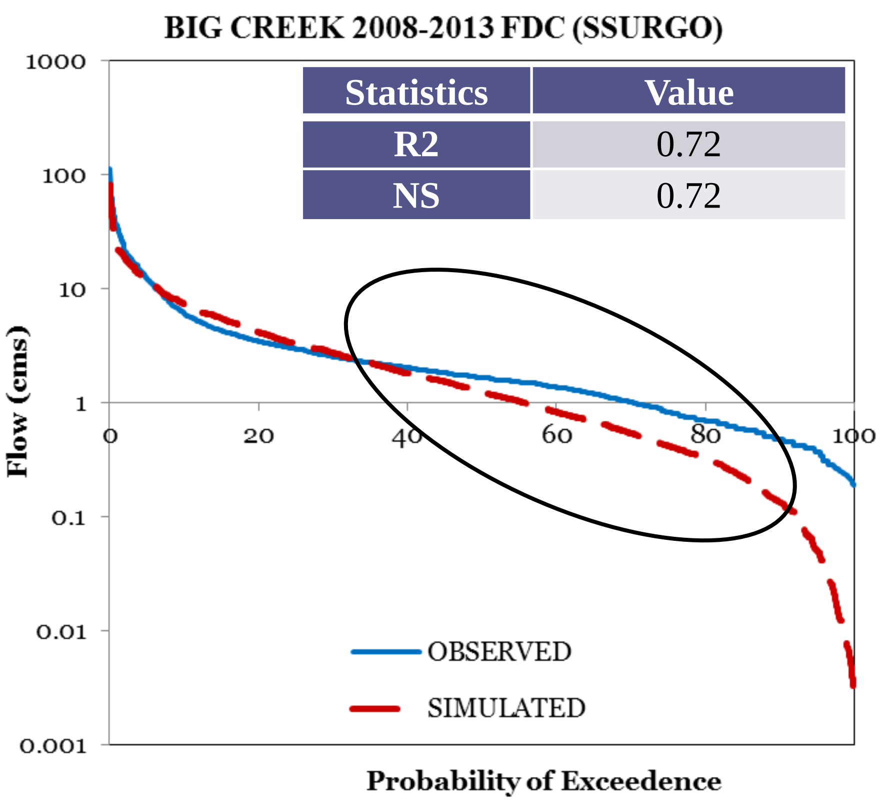


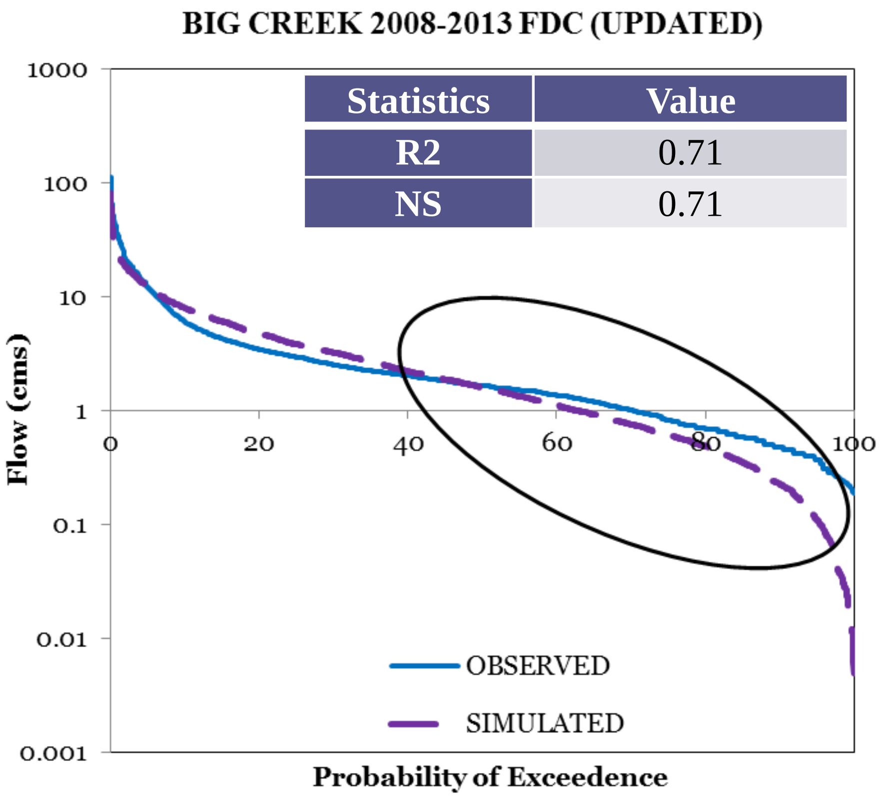


Flow duration curves (FDC) of daily flow of Big Creek

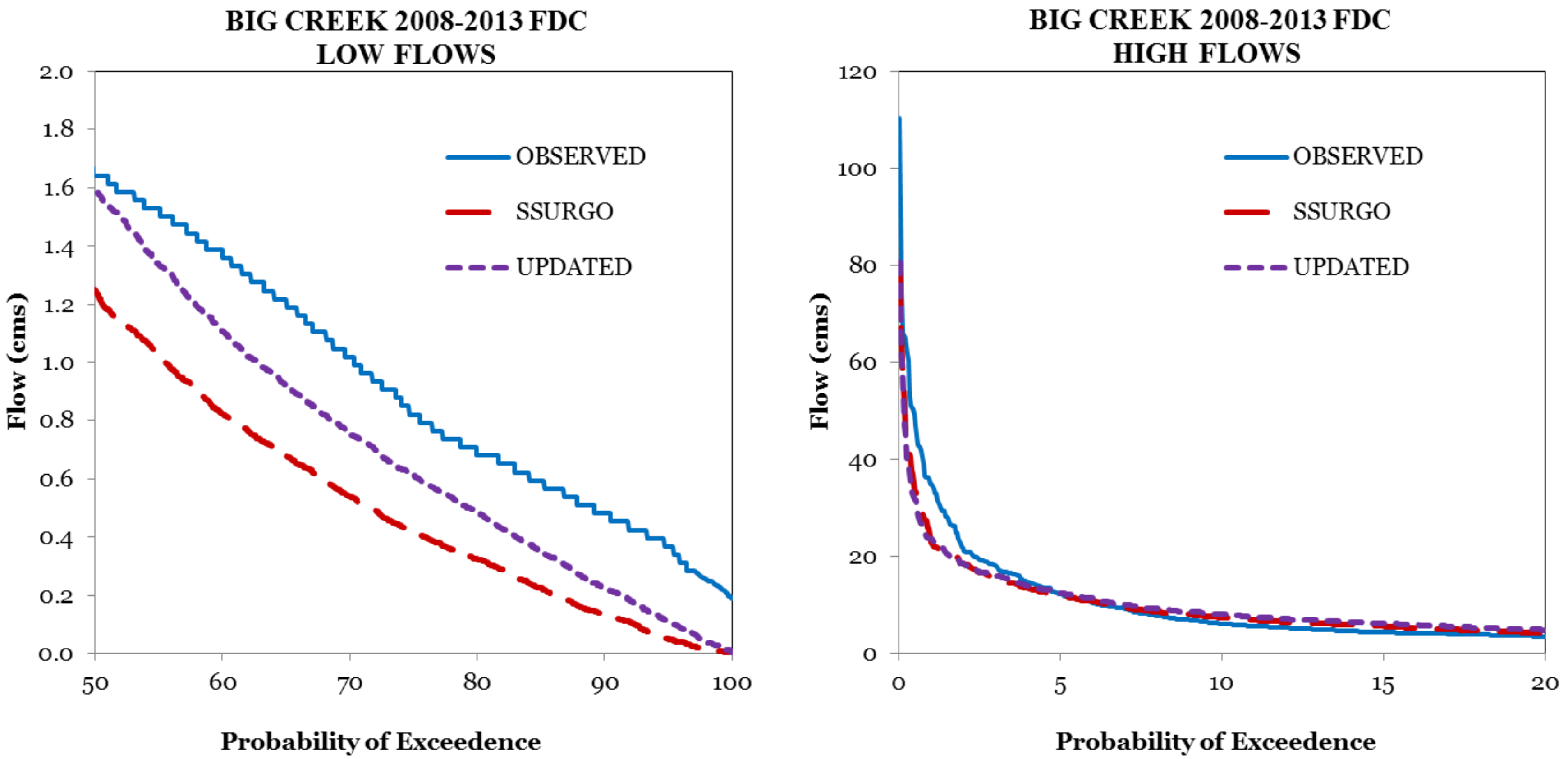
RESULTS

- Comparison of model outputs in Big Creek using default SSURGO parameters and updated parameters





RESULTS


BIG CREEK 2008-2013 FDC
LOW FLOWS
Flow (cms)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
50
60
70
80
90
100
Probability of Exceedence
OBSERVED
SSURGO
UPDATED
BIG CREEK 2008-2013 FDC
HIGH FLOWS
Flow (cms)
120
100
80
60
40
20
0
0
5
10
15
20
Probability of Exceedence
OBSERVED
SSURGO
UPDATED

CONCLUSIONS

- Overall discharge simulations for watershed were similar, but improvement was observed in low flows when changed soil parameters (Ksat and bulk density) were used.
- Use of updated SSURGO and LULC based SWAT is preferable for discharge modeling. The advantages of using updated SSURGO parameters can be further realized in applications, including estimation of low and medium flows over mesoscale watersheds and more importantly, highly urbanized watersheds.

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QUESTIONS ?