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Using SWAT to Simulate Streamflow and Evaluate Sediment Yield in Xinjiang River Basin

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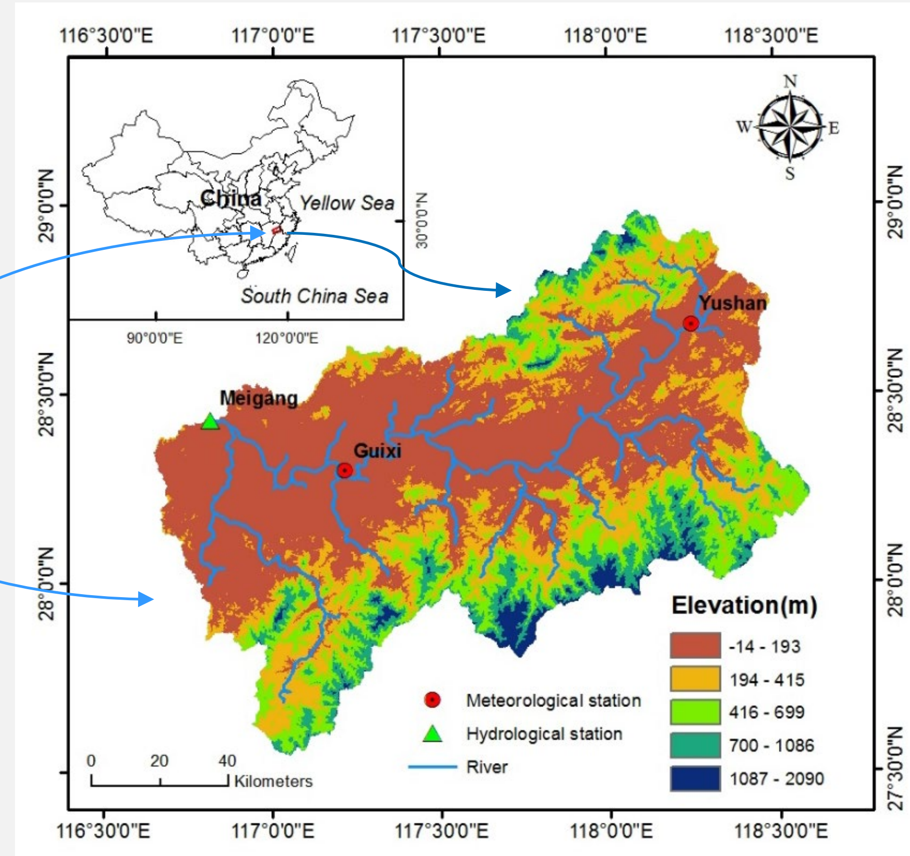
Introduction

- Poyang Lake is the largest freshwater lake in China
- It is a significant ecological biodiversity hotspot in the world
- This region is facing some serious environmental issues, such as frequent flood, drought, and soil erosion.

Study Area

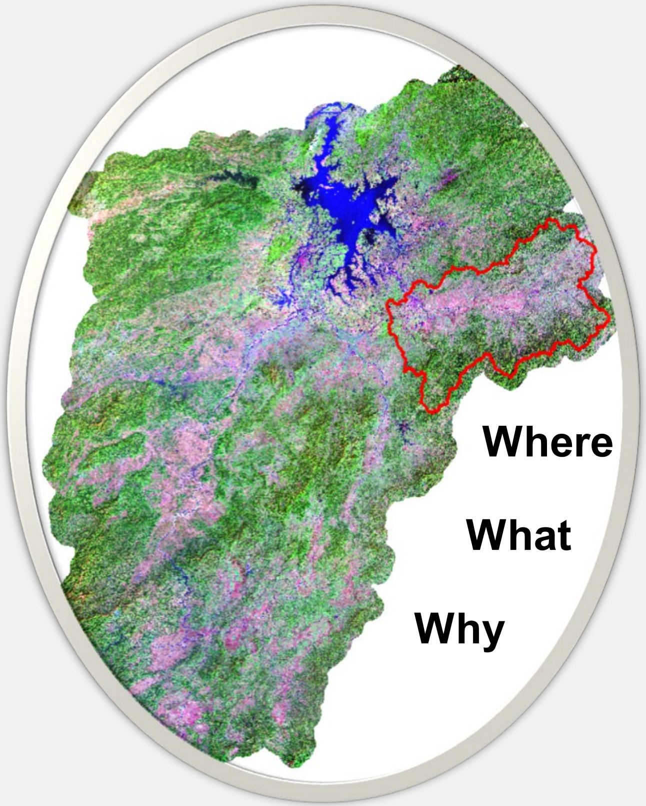


Topography, rivers, hydrological and meteorological stations of the Xinjiang River Basin

The Purpose

Simulating Flow and Sediment

Identify Soil Erosion Hotspot



Questions:

1. Where is sediment from in the area?
2. What is spatial distribution of average annual sediment yield?
3. Why is soil erosion severe in the area?

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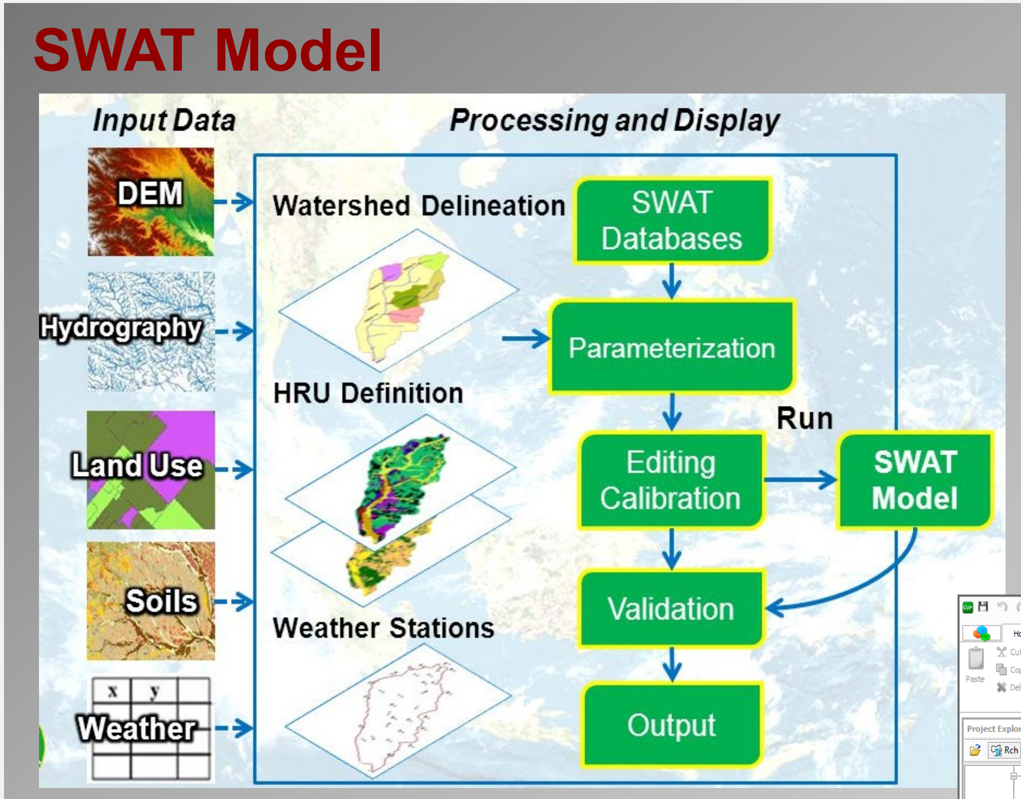
Materials and Methods



SWAT model

ArcSWAT version 5.1.6.2

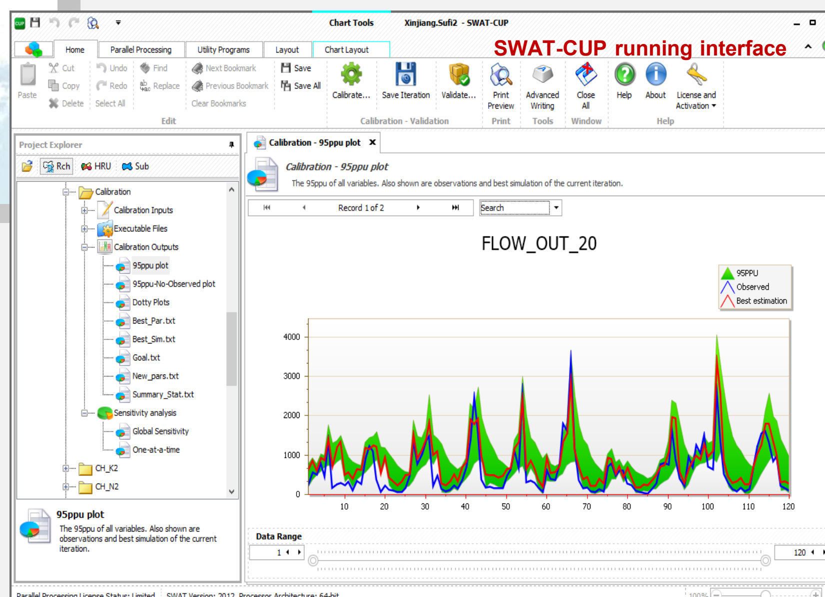
$$SW_t = SW_0 + \sum_{n=1}^{t}\left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right)$$

SWAT-CUP

SWAT Calibration Uncertainty Procedure

GIS and Statistic

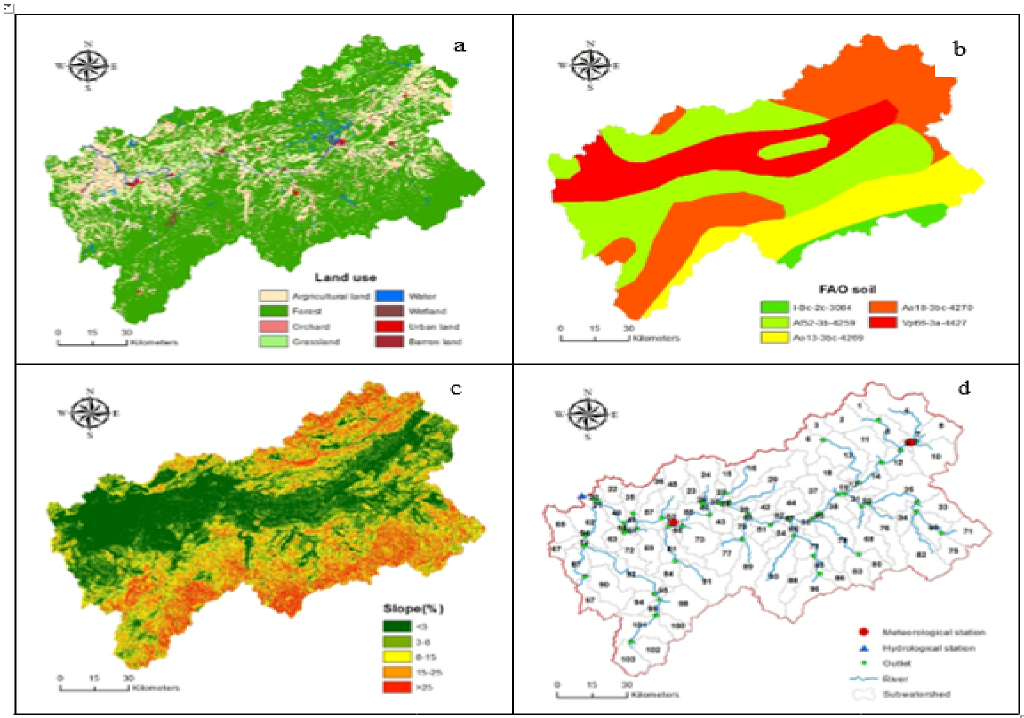
ArcGIS and R^2, NSE, PBIAS, RSR, p-factor, r-factor



Data input

a) LULC 2005

b) FAO soil;



c) Slope classification based on DEM

d) meteorological & hydrological stations

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Model evaluation

How did we evaluate the SWAT model?

NSE	R^2	p-factor	r-factor
->1, Good <0, Bad	0->1, Good	0->1, Good	0<-∞ ,Good

Performance ratings of recommended statistics for streamflow simulation (modified from Ayele et. al 2017 and Moriasi et al., 2007)

Performance Rating	R^2	NSE	RSR	PBIAS (%)	
				Streamflow	Sediment
Very Good	$0.7<R^2≤1$	0.75< NSE ≤1	0≤ RSR ≤0.5	PBIAS <±10	PBIAS <±15
Good	$0.6<R^2≤0.7$	0.65< NSE ≤0.75	0.5< RSR ≤0.6	±10≤ PBIAS <±15	±15≤ PBIAS <±30
Satisfactory	$0.5<R^2≤0.6$	0.5< NSE ≤0.65	0.6< RSR ≤0.7	±15≤ PBIAS <±25	±30≤ PBIAS <±55
Unsatisfactory	$R^2≤0.5$	NSE < 0.5	RSR >0.7	PBIAS ≥±25	PBIAS ≥±55

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Calibrated streamflow parameters value and sensitivity rank

Table 1
Calibrated streamflow parameters value for monthly and daily

Monthly			Daily		
Rank	Parameter name	Fitted value	Rank	Parameter name	Fitted value
1	V_ALPHA_BF	0.167	1	V_ALPHA_BF	0.700
2	V_CH_N2	0.007	2	V_CH_N2	0.022
3	V_CH_K2	54.491	3	V_CH_K2	482.250
4	R_CN2	-0.175	4	R_CN2	-0.196
5	V_GW_REVAP	0.185	5	V_GW_REVAP	0.176
6	R_CH_S2	8.610	6	R_OV_N	19.039
7	R_OV_N	22.712	7	R_CH_S2	3.294
8	V_GW_DELAY	494.500			

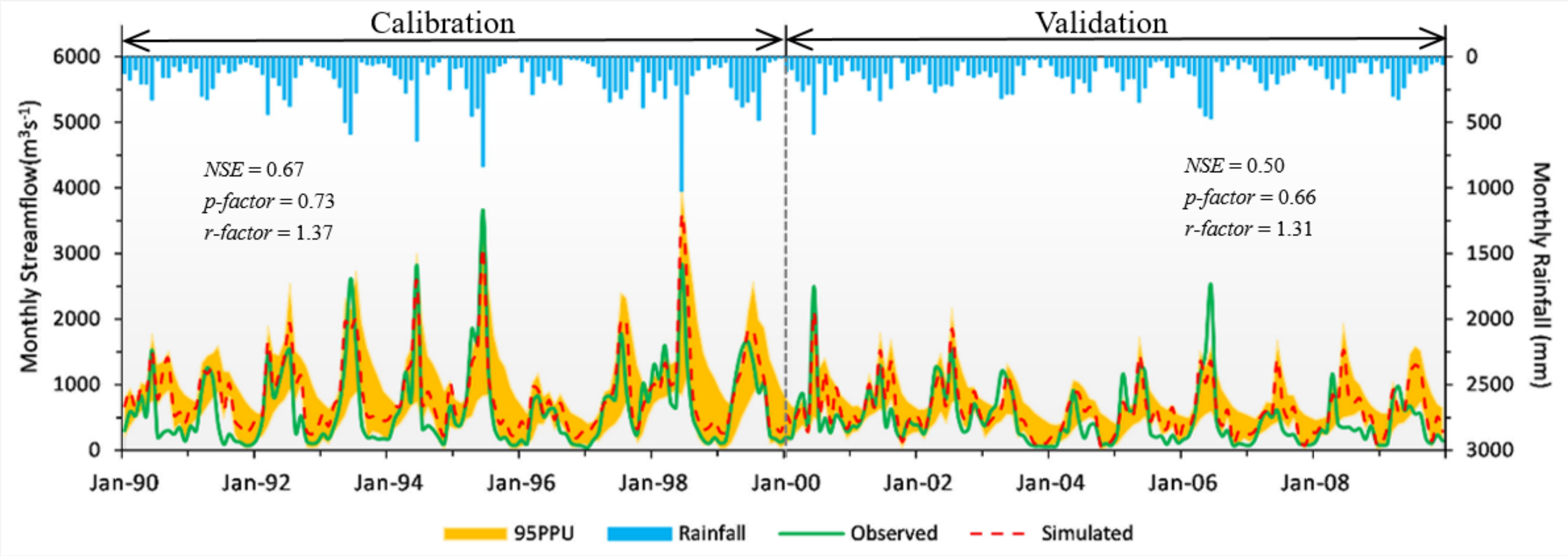
Table 2

Calibrated sediment parameters and their sensitivity rank

Parameter	Range	Rank	t-test	p-value	Fitted value
v_SPCON.bsn	0.0001-0.01	1	3.82	0.00	0.005
v_USLE_P.mgt	0-1	2	2.58	0.01	0.522
r_CH_EROD.rte	0-1	3	-0.49	0.63	0.602
v_SPEXP.bsn	1-1.5	4	-0.15	0.88	1.281
r_CH_COV.rte	-0.001-1	5	-0.06	0.95	0.369

Monthly Streamflow Simulations

Comparison of observed and simulated monthly streamflow hydrograph with 95PPU for calibration and validation



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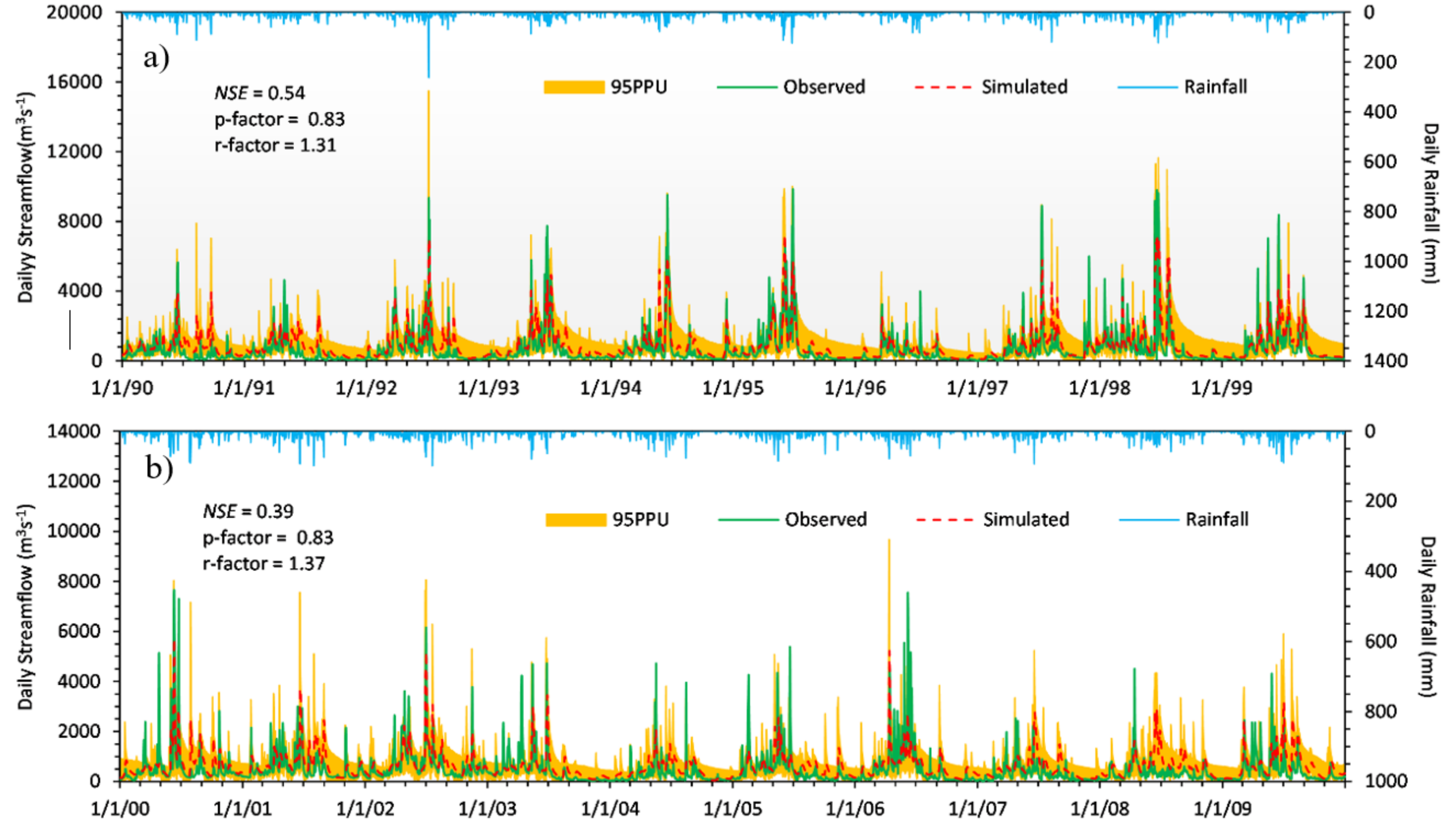
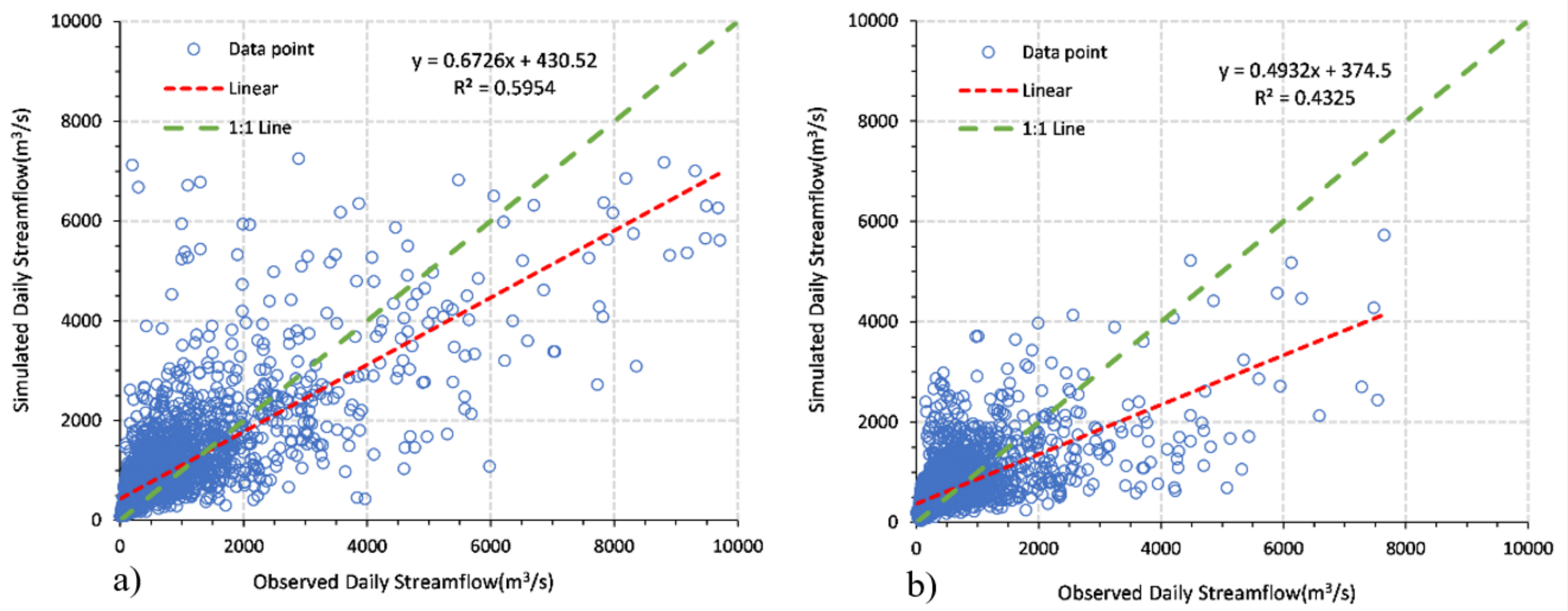
Daily Streamflow Simulations



daily observe streamflow, 95PPU and best simulated streamflow: a) calibration; b) validation

Daily Streamflow Simulations



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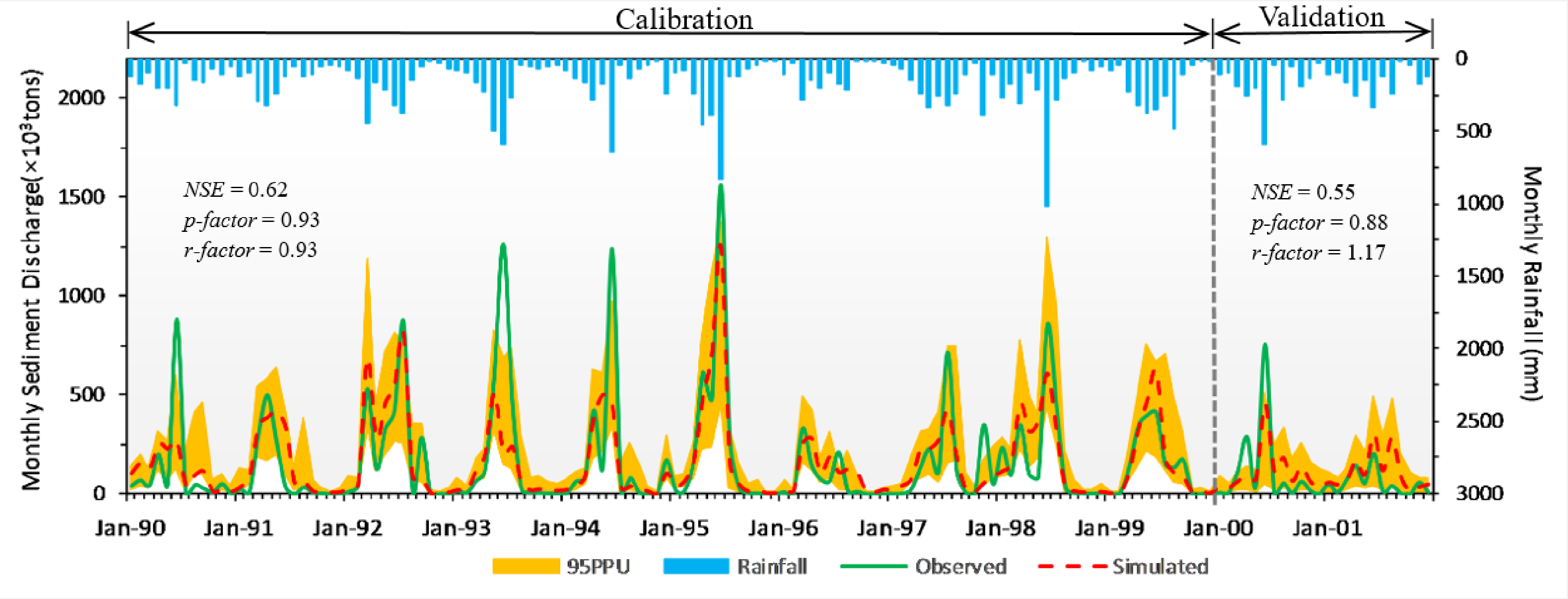
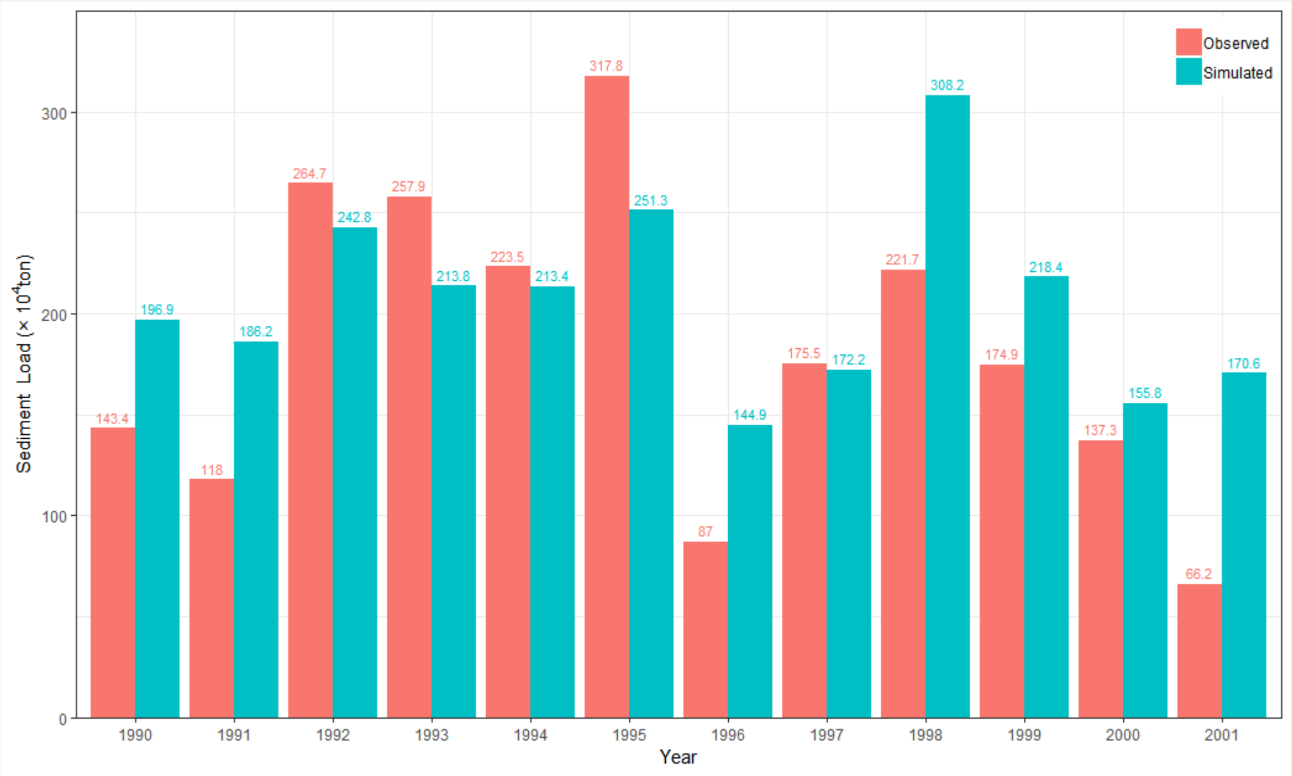
Monthly Sediment Simulation

Monthly sediment discharge for calibration (1990-1999) and validation (2000-2001)



Annual observed and simulated suspended sediment load at Meigang station



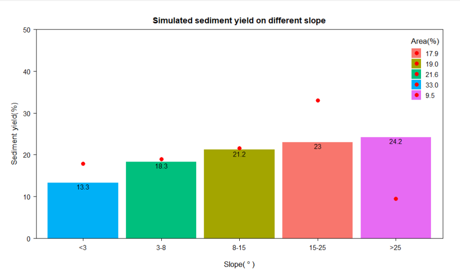
Observed suspended sediment load at Meigang station

Authors	Periods	Observed sediment ($\times 10^4$ ton/year)
Guo, *et al.* (2006)	1991-2001	200
Huang (2008)	-	261
Sun, *et al.* (2010)	1956-2005	210
Min, *et al.* (2011)	1956-2005	212
Luo, *et al.* (2014)	1956-2008	204

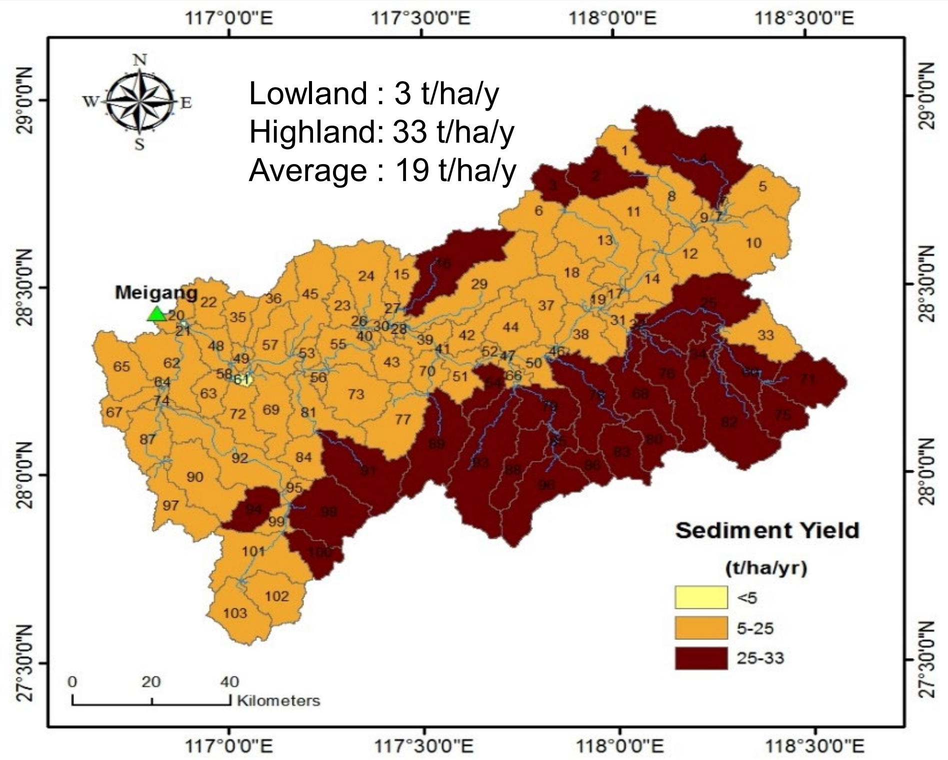
Average Sediment Load($\times 10^4$ ton) during 1990-2001	
Observed	Simulated
182.3	206.2

Results

Slope

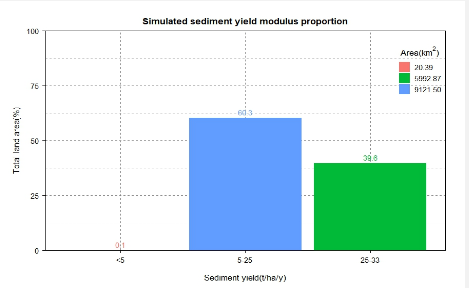


Spatial distribution of average annual sediment yield

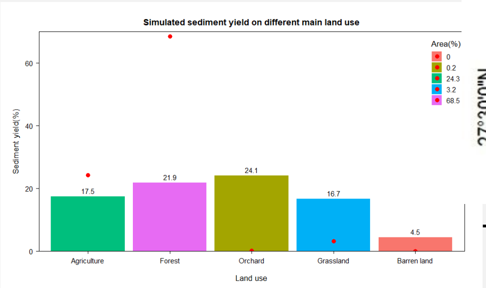


The average result is close to 20.7 t/ha/year from Lu, *et al.* (2011).

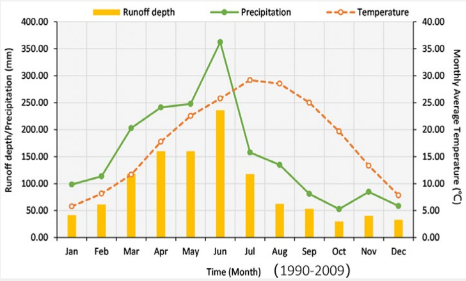
Sediment yield modulus



Land use



Climate condition



Discussion & Conclusions

Poyang Lake National Wetland Park

1. Most sensitive parameters

base flow alpha factor and linear factor for channel sediment routing.

2. Where are most sediment yield source from

>25° slope, Orchard and barren land

3. What is sediment yield spatial distribution

South bank, Highland > Lowland, the steeper the slope is, the more the sediment yield proportion is. 99.9% land suffer from >5 t/ha/y sediment yield ratio.

4. How to prevent soil erosion?

Change inappropriate tillage practices on the areas with >25° slope. Adding vegetation cover on orchard and barren land.

Thank You!

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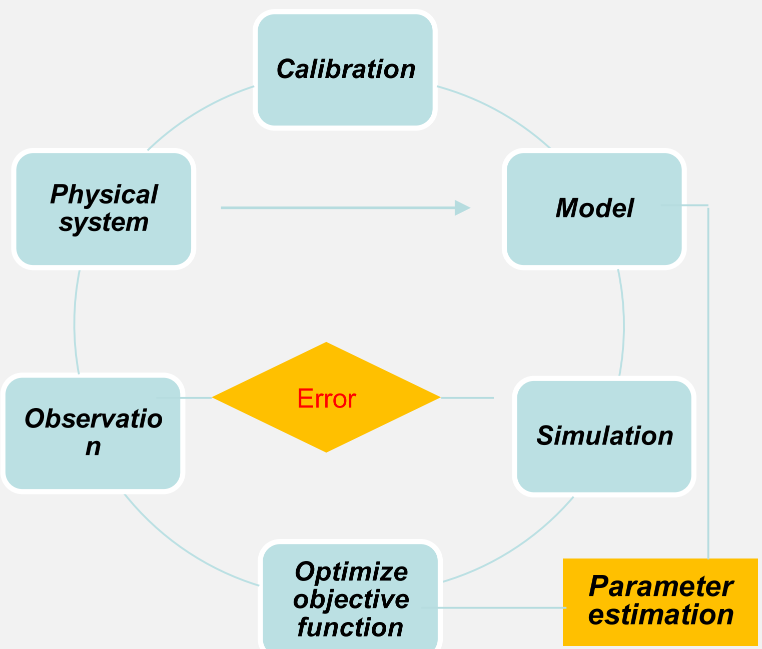
Model Sensitivity Analysis

Calibration streamflow parameters and their adjustable range in sensitivity analysis

No.	Parameter name	Parameter description	Range	Calibration					
				Monthly			Daily		
				t-test	*p-value*	Rank	*t-test*	*p-value*	Rank
1	V__ALPHA_BF.gw	Baseflow alpha factor (1/days)	0-1	35.76	0.00	1	17.15	0.00	1
2	V__CH_N2.rte	Manning's "n" value for the main channel.	-0.01-0.3	-16.96	0.00	2	-9.16	0.00	2
3	V__CH_K2.rte	Effective hydraulic conductivity in main channel alluvium (mm/hr).	-0.01-500	-15.91	0.00	3	-6.19	0.00	3
4	R__CN2.mgt	SCS runoff curve number II	-0.2-0.2	-7.65	0.00	4	-5.82	0.00	4
5	V__GW_REVAP.gw	Groundwater "revap" coefficient	0.02-0.2	5.31	0.00	5	3.59	0.00	5
6	R__CH_S2.rte	Average slope of main channel (m/m).	-0.001-10	4.26	0.00	6	2.09	0.04	7
7	R__OV_N.hru	Manning's "n" valu e for overland flow	0.01-30	-4.21	0.00	7	2.34	0.02	6
8	V__GW_DELAY.gw	Groundwater delay (days)	100-500	2.47	0.01	8	-0.46	0.65	15
9	R__SOL_K (1).sol	Saturated hydraulic conductivity at the 1^{st} soil layer (mm/hr).	0-100	-2.04	0.04	9	-1.78	0.08	9
10	V__SOL_Z (1).sol	Depth from soil surface to bottom of the 1^{st} soil layer (mm).	0-300	0.95	0.34	10	0.14	0.89	18
11	R__SOL_BD (1).sol	Moist bulk density at the 1^{st} soil layer (g/cm^3).	0.9-2.5	-0.90	0.37	11	0.51	0.62	14
12	R__ALPHA_BNK.rte	Baseflow alpha factor for bank storage (days).	0-1	-0.85	0.40	12	-0.46	0.65	16
13	R__EPCO.hru	Plant uptake compensation factor.	0-1	-0.59	0.55	13	-0.01	0.99	20
14	A__ESCO.hru	Soil evaporation compensation factor.	0-0.2	0.56	0.58	14	0.95	0.34	11
15	A__SURLAG.bsn	Surface runoff lag time.	0.05-24	0.55	0.58	15	0.70	0.48	13
16	R__SOL_AWC (1).sol	Available water capacity of the 1^{st} soil layer (mm H_2O/mm soil)	0-1	0.46	0.64	16	-0.01	0.99	19
17	A__GWQMN.gw	Threshold depth of water in the shallow aquifer required for return flow to occur (mm H_2O)	0-25	-0.43	0.67	17	1.59	0.11	10
18	V__REVAPMN.gw	Threshold depth of water in the shallow aquifer for "revap" to occur (mm H_2O).	0-500	0.40	0.69	18	0.94	0.35	12
19	R__HRU_SLP.hru	Average slope steepness(m/m)	0-1	-0.39	0.69	19	0.26	0.80	17
20	R__SLSUBBSN.hru	Average slope length (m).	10-150	-0.23	0.81	20	-1.83	0.07	8

Model Calibration and Validation

There is an conceptualization of model calibration



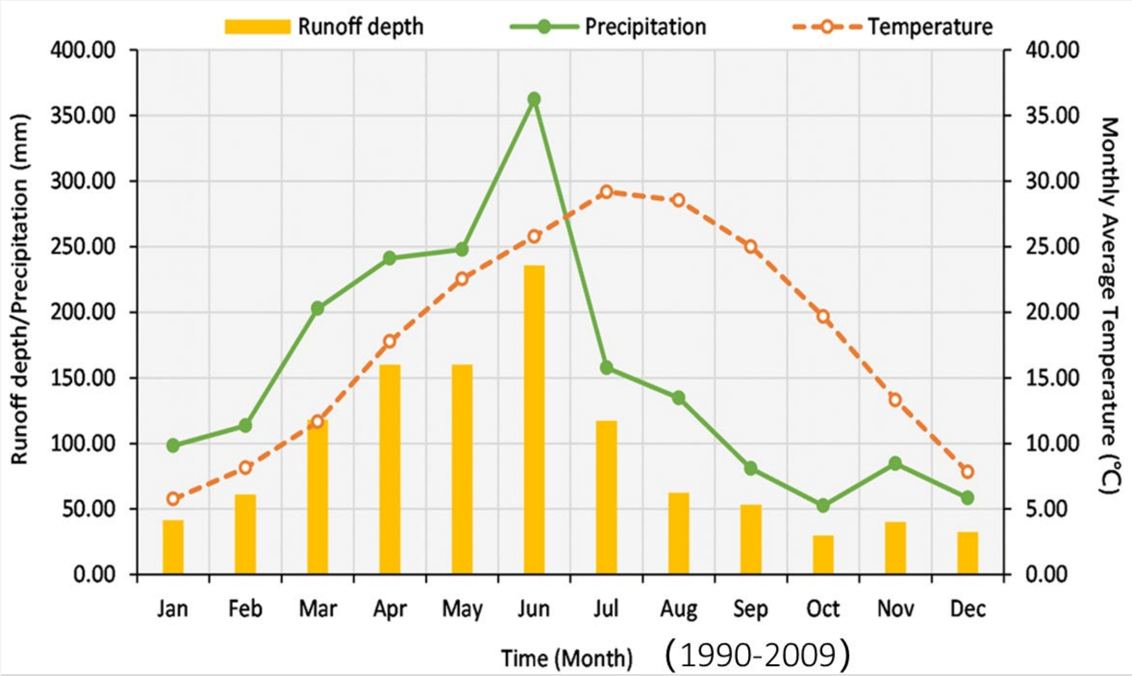
Calibration

A procedure where the difference between model simulation and observation are minimized.

Validation

Validation is like calibration except model parameters are not modified

Natural Condition and Human Impact on Soil Erosion



- **Climate**
- **Rainfall**
- **Soil**
- **Human Impact**