Assessment of sediment and carbon flux in a tropical watershed: the Red River study case (China and Vietnam)

Xi WEI

Supervisors: Sabine SAUVAGE, Jose-Miguel SANCHEZ-PEREZ, Thi Phuong Quynh LE

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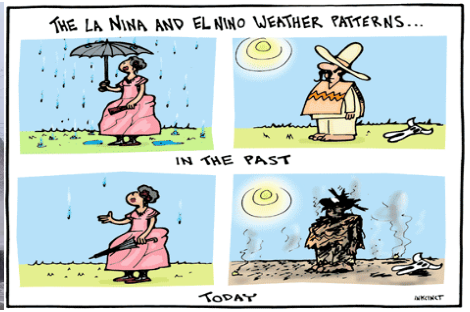
1. Context

- **Climate:**
  - Temperature
  - Precipitation
  - Typhoon
  - El Nino and La Nina
  - …

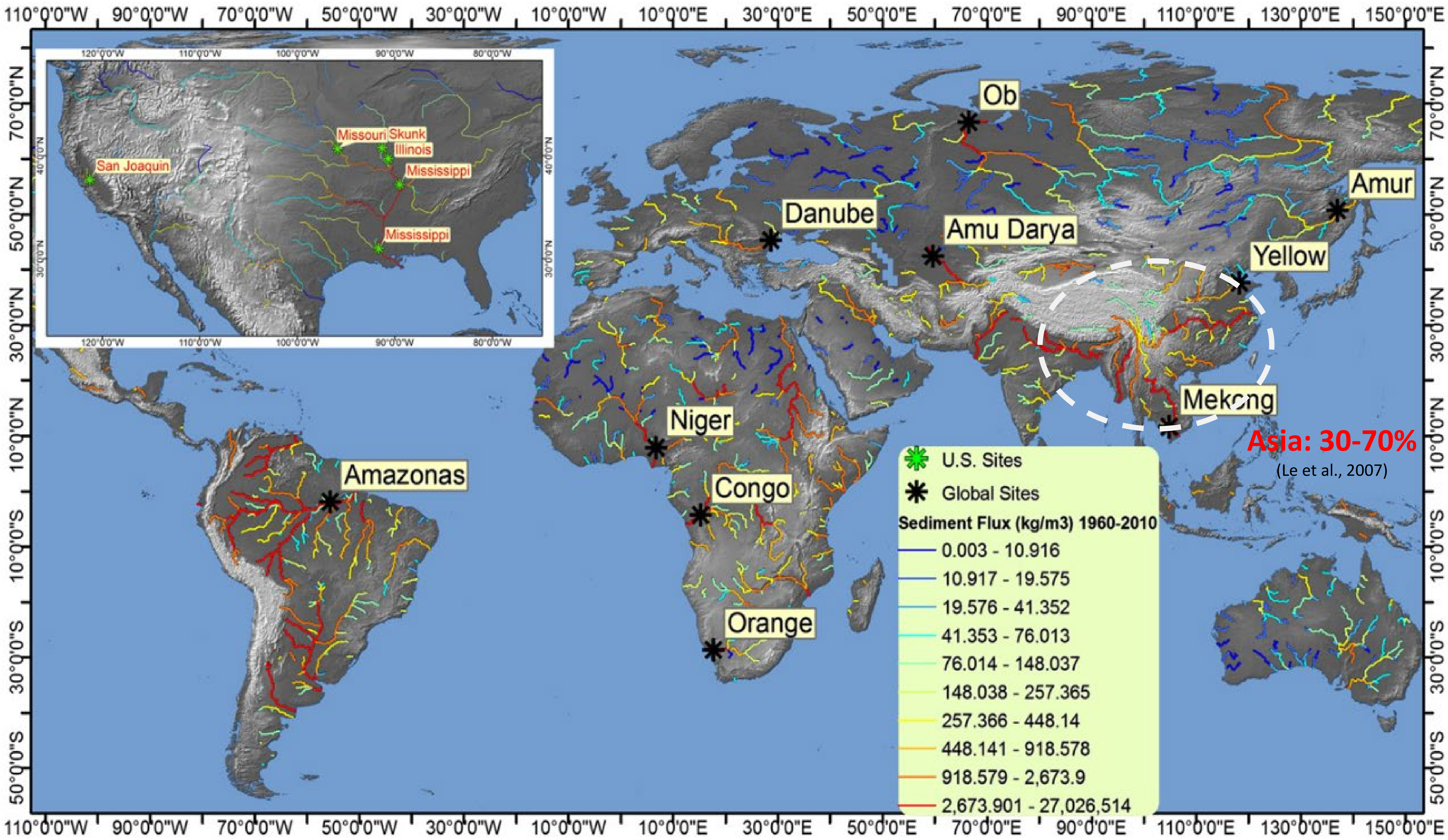


Impact to:

Hydrology
Sediment
Nutrients Transfer

- **Human disturbance:**
  - Deforestation
  - Urbanization
  - Agricultural Activities
  - Dam Constructions
  - …

1. Context—Sediment

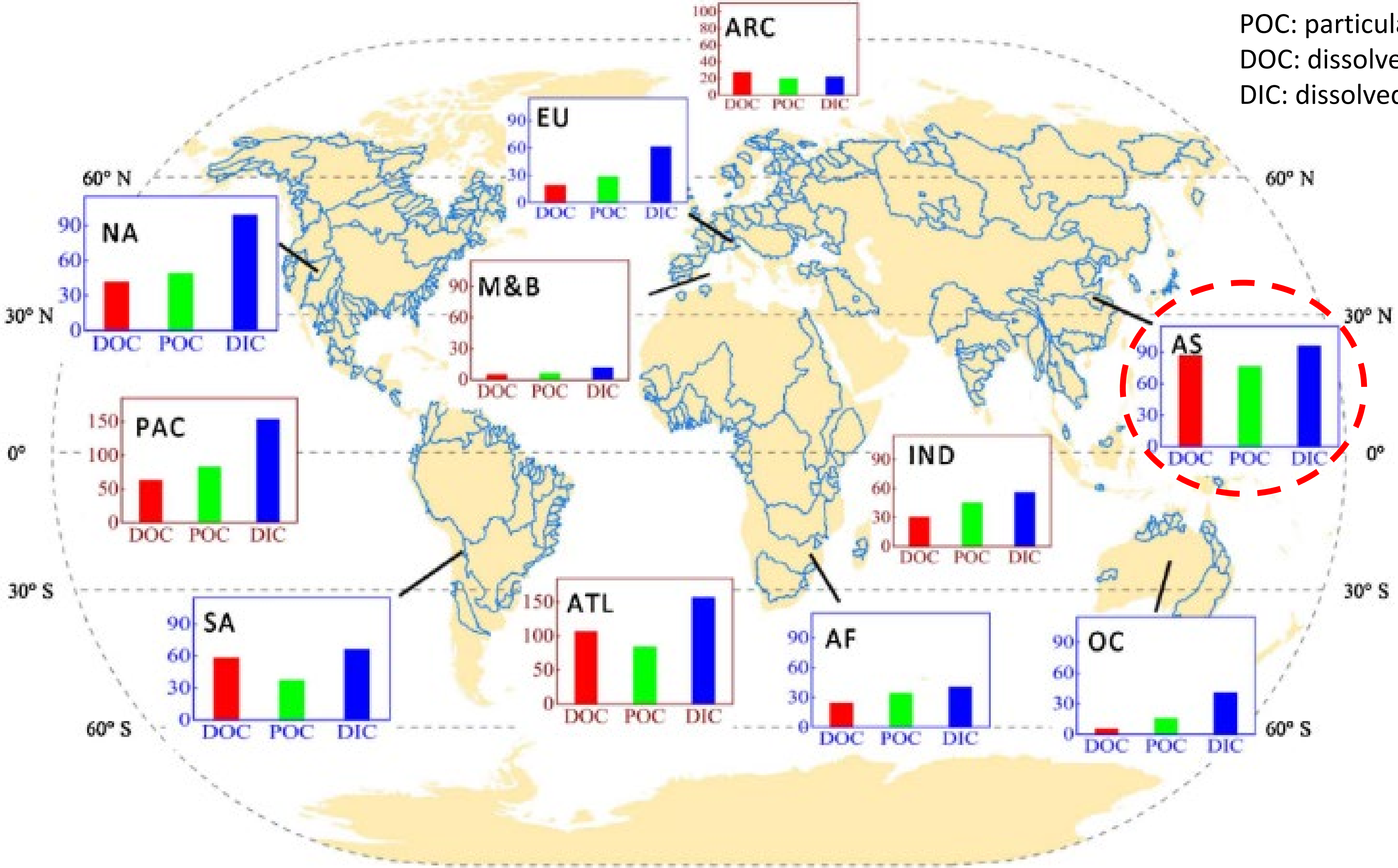


1960-2010 simulated suspended sediment flux

(picture extracted from Cohen et al., 2014)

1. Context—Carbon

POC: particular organic carbon
DOC: dissolved organic carbon
DIC: dissolved inorganic carbon



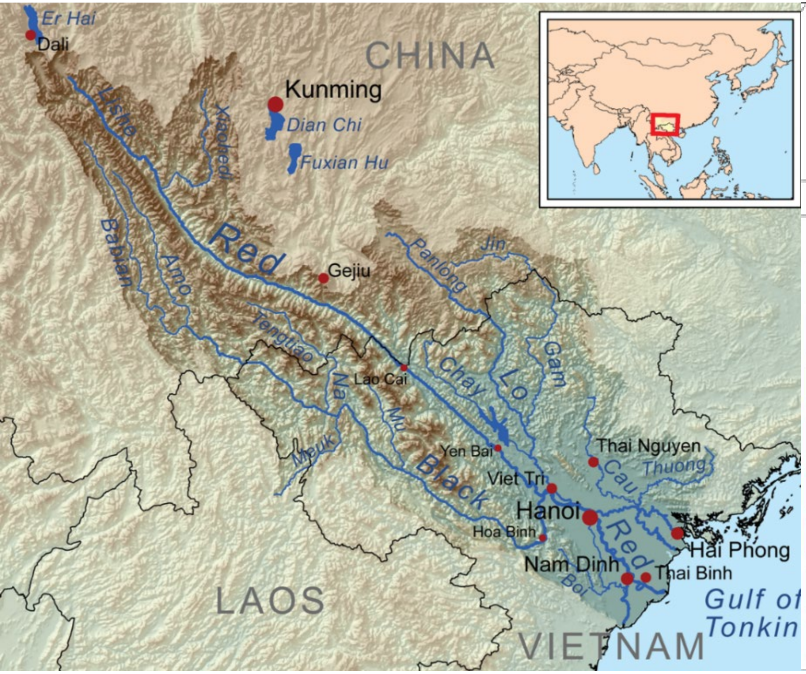
Spatial variation of riverine DOC, POC, and DIC flux (Tg C/yr)
(picture extracted from Li et al.,2017.)

1. Context—The Example of the Red River Watershed in Asia

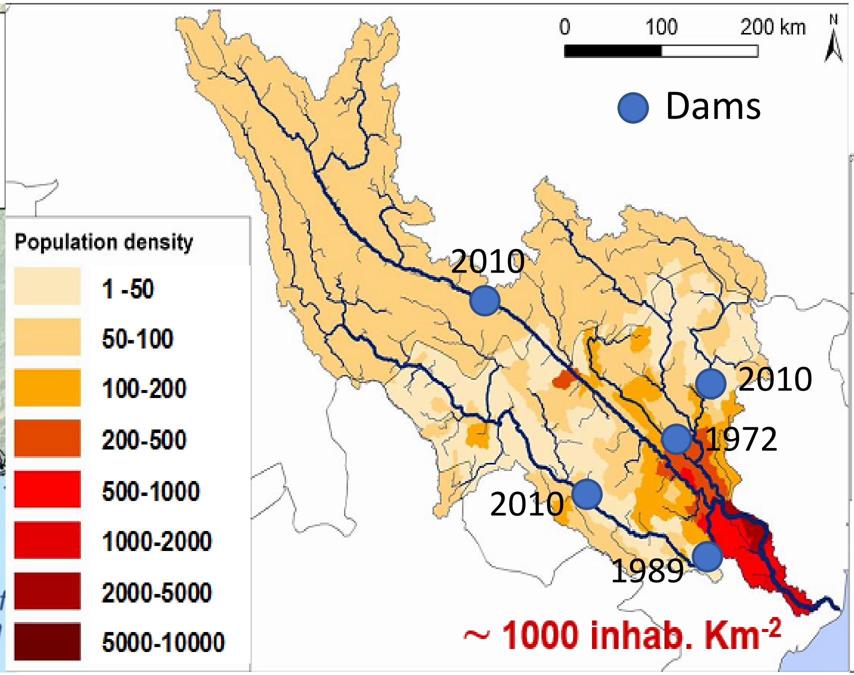
an international river
the second largest river in Vietnam

high population density, urbanization

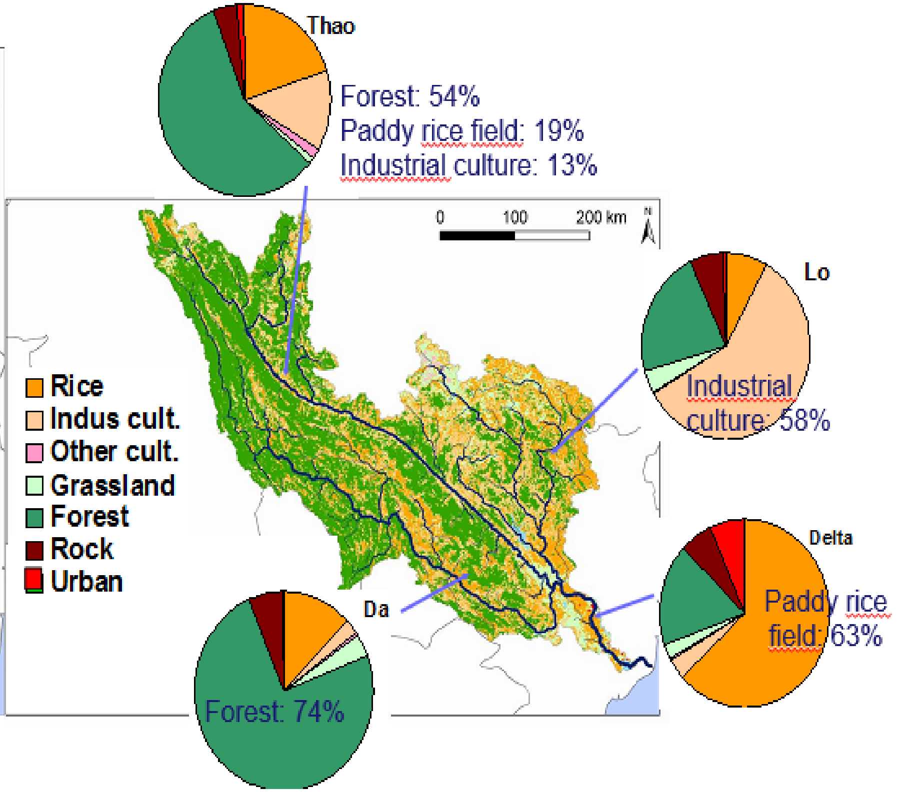
intensive agricultural activities



The Red River watershed



Population density of the Red River
(Picture extracted from Le, 2005)



Land use of different sub-basins
(Picture extracted from Le, 2005)

Meteorological–hydrological effect

Dam

Management

(Barton et al., 2004; Le et al., 2007; Dang et al., 2010; Vinh et al., 2014; Schoenbohm et al., 2014 ; Lu et al., 2015; Le et al., 2017)

1. Context—Recent Studies & Objectives

- Statistic Analysis

- Modeling

monthly scale

daily scale (short period, on delta part, only Q or SS)

Reference:
(He et al.,2007; Le et al., 2007 ; Dang et al.,2010; Le et al., 2010; Minh et al., 2010; Vinh et al.,2014; Lu et al.,2015; Le et al., 2017; Hiep et al., 2018)

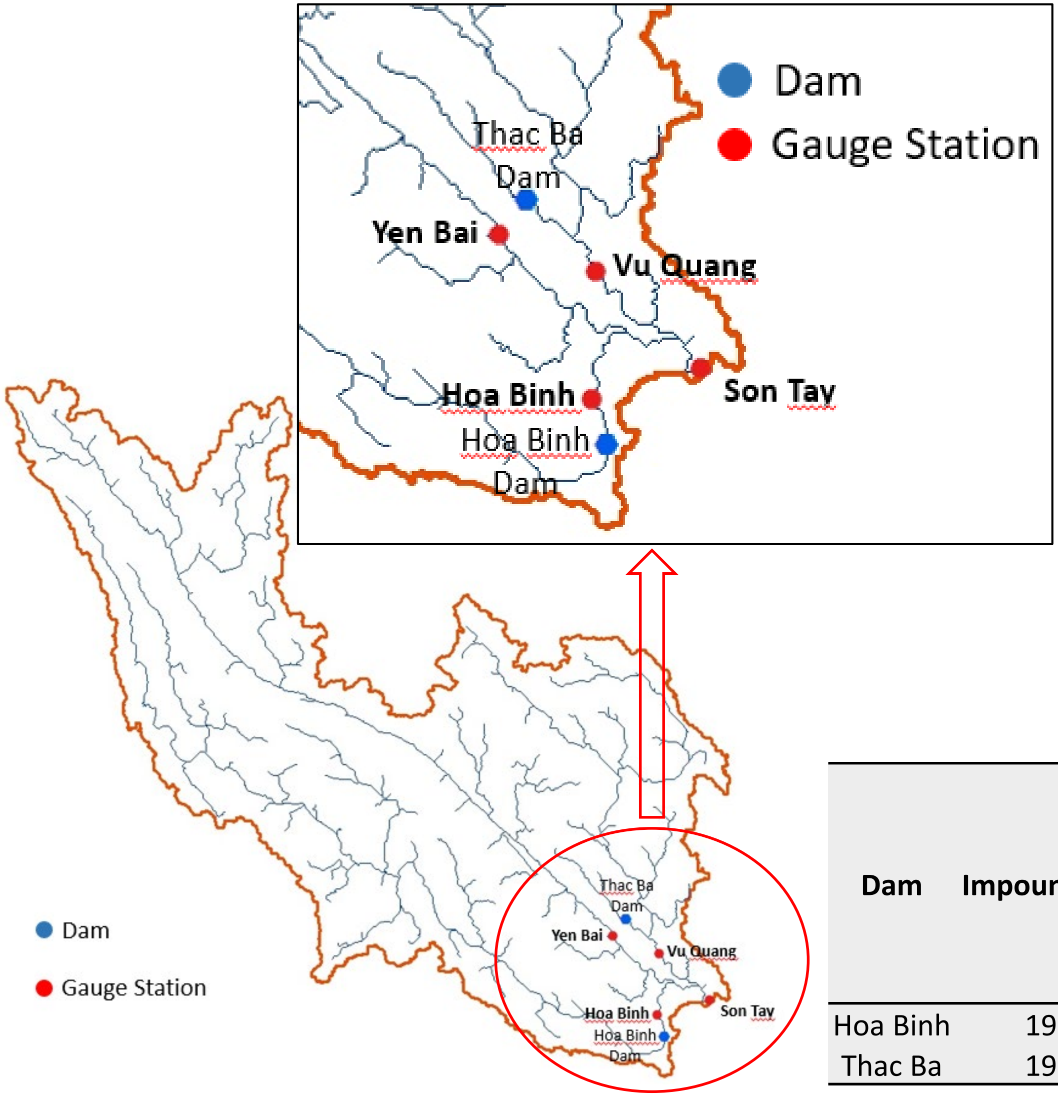
➢ Daily-scale long-term simulation of Q, SS and C

- to better understand the dynamic changes and the key influence factors
- to quantify the export to the delta part

➢ Different scenarios

- to develop a comprehensive understanding of the linkage between land use, human activities and climate in the watershed
- to predict the future changes
- to provide the reference and information for the river and agriculture management

2. Study Site—The Upstream of the Delta—Inputs and Database



Area of the study site: 137 230 km^2
Elevation: 3103 to 6 m
Mean Discharge at the outlet: 3480 m^3/s (IMHEN (1), from 1690 to 2010)
Mean Precipitations: 1518-1835 mm/yr (Le et al., 2012; Simons et al., 2016)

Data Type	Period	Scale	Source
Precipitation	1998-2016	daily	TRMM (2)
Temperature	1998-31 July 2014	daily	CFSR (3)
Q	2000-2010	daily	IMHEN
SS	2000-2010	daily	IMHEN
POC	Yen Bai: 2008-2010, 2013-2015 Son Tay: 2013-2015 Hoa Binh: 2008-2010, 2013-2015 Vu Quang: 2008-2010, 2013-2015	once/month	T.P.Q LE (4)
DOC	Yen Bai: 2003-2004, 2008-2010, 2012-2015 Son Tay: 2003-2004, 2013-2015 Hoa Binh: 2003-2004, 2008-2010, 2012-2015 Vu Quang: 2003-2004, 2008-2010, 2012-2015	once/month	T.P.Q LE

Dam	Impoundment	River Basin (km^2)	Capacity (Mm^3)	Surface (km^2)	Water Level (m)	Mean Depth (m)	Mean Annual Water Discharge (m^3/s)	Maximum Water Discharge (m^3/s)
Hoa Binh	1989	57285	9.5	208	115	50	1781	2400
Thac Ba	1972	6170	2.9	235	58	42	191	420

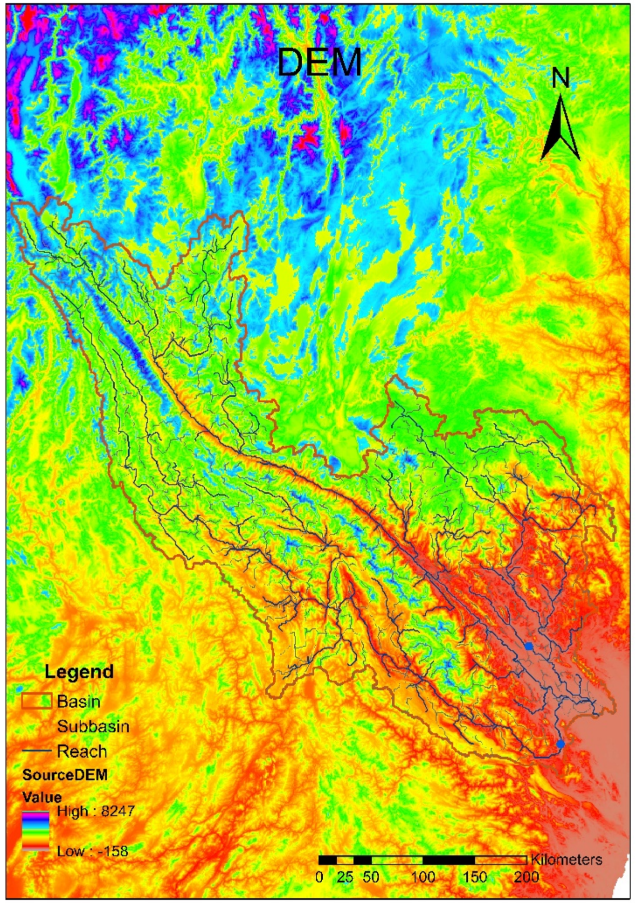
(1)IMHE: Institute of Meteorology, Hydrology and Environment, Vietnam
(2)TRMM: The Tropical Rainfall Measuring Mission (https://pmm.nasa.gov/TRMM)
(3)CFSR: Climate Forecast System Reanalysis (https://globalweather.tamu.edu/)
(4)T.P.Q LE: Thi Phuong Quynh Le, Laboratory of Environmental Chemistry, Institute of Natural Product Chemistry, Vietnam Academy of Science and Technology

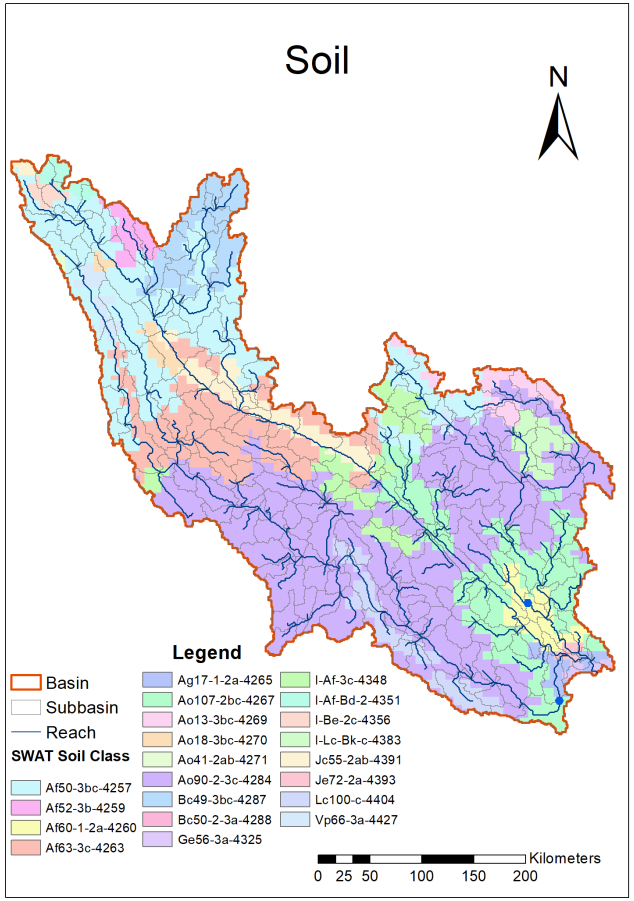
3. Inputs and Database

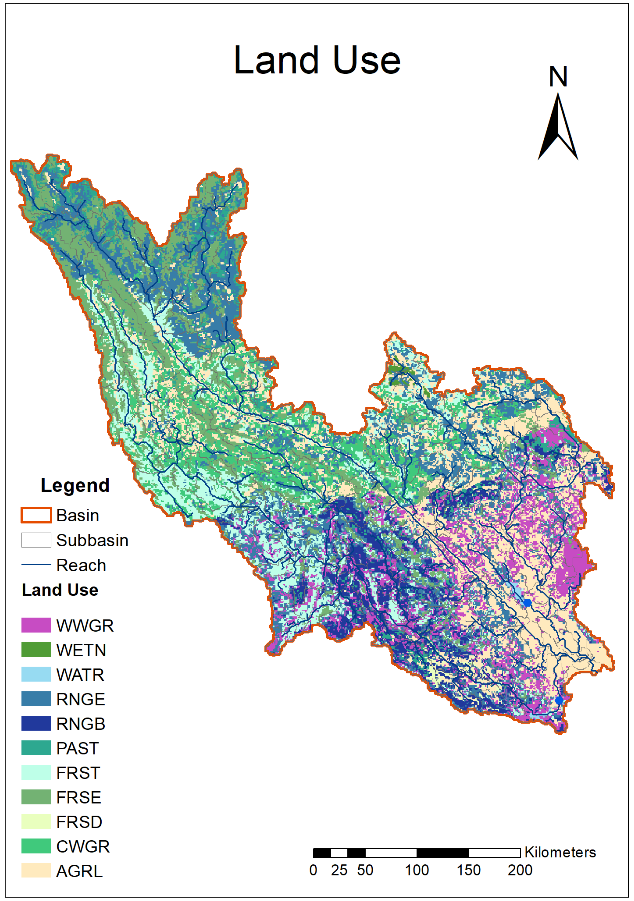
- **SWAT Inputs**

Subbasins: 242
HRU: 1309

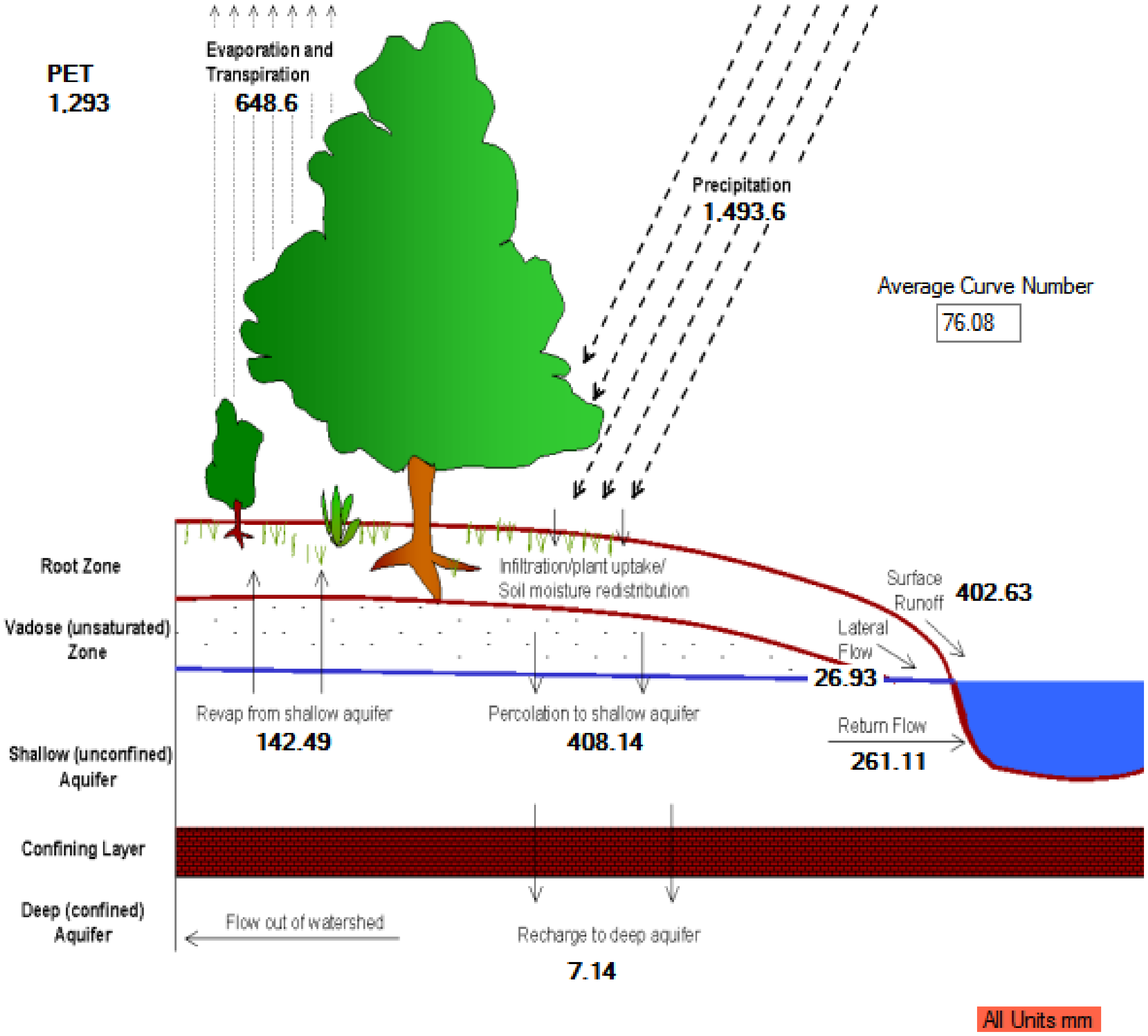
Data Type	Resolution	Source
DEM	0.9*0.9 km	Shuttle Radar Topography Mission (SRTM) (http://www2.jpl.nasa.gov/srtm)
Soil	0.9*0.9km	Harmonized World Soil Database (http://webarchive.iiasa.ac.at/Research/LUC)
Land Use	0.9*0.9km	Global Land Cover 2000 database (http://forobs.jrc.ec.europa.eu/products/glc2000)







4. Results—Water Balance



- **precipitation:**

reference: 1518~1835 mm (T.P.Q. LE et al., 2012; G. SIMONS et al., 2016)
TRMM: 1494mm

- **water yield:**

46% of Precipitation

real: 669mm
sim: 693mm

- **ETP:**

reference: 924~1062 mm (T.P.Q. LE et al., 2012)
sim: 1293 mm

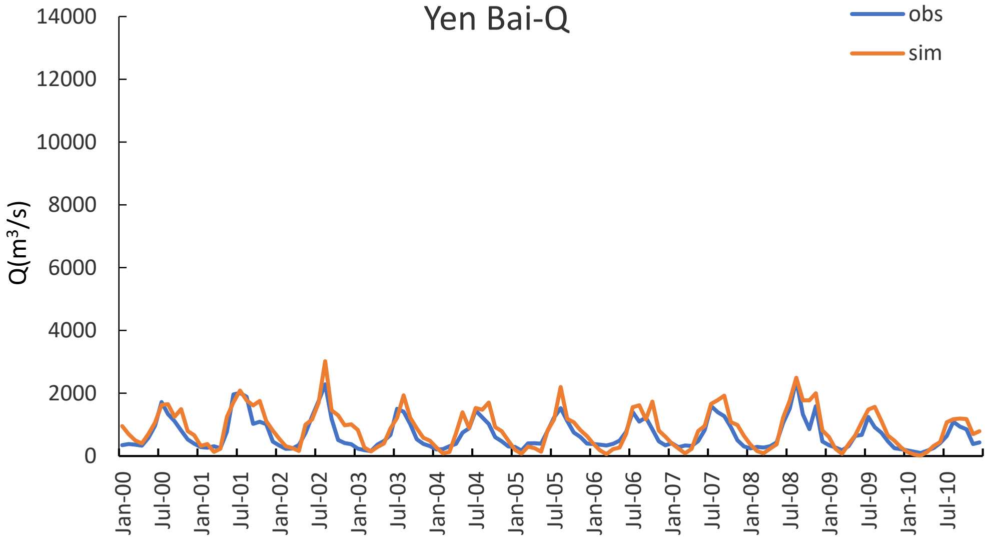
- **ETA:**

43%

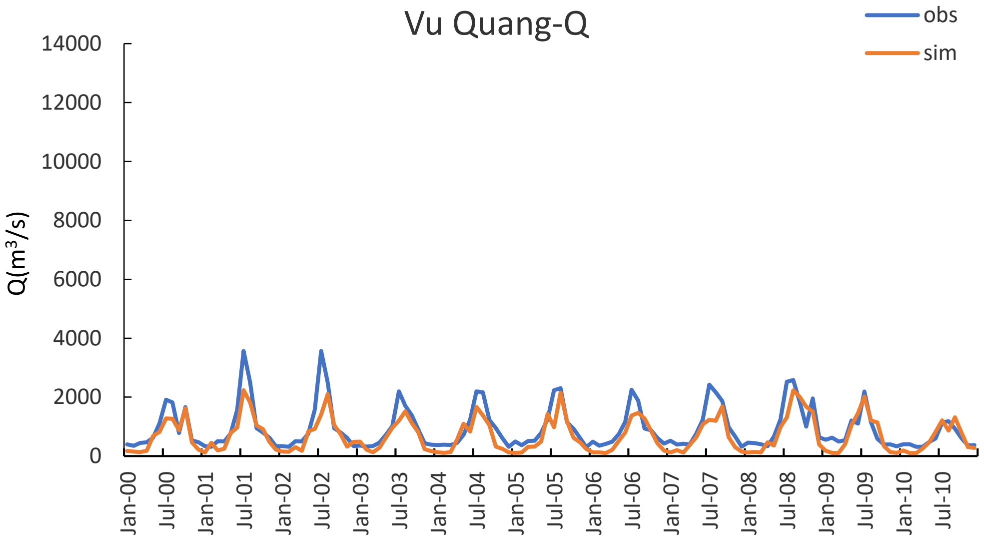
reference: 832~1117 mm (T.P.Q. LE et al., 2012; G. SIMONS et al., 2016)
sim: 649 mm

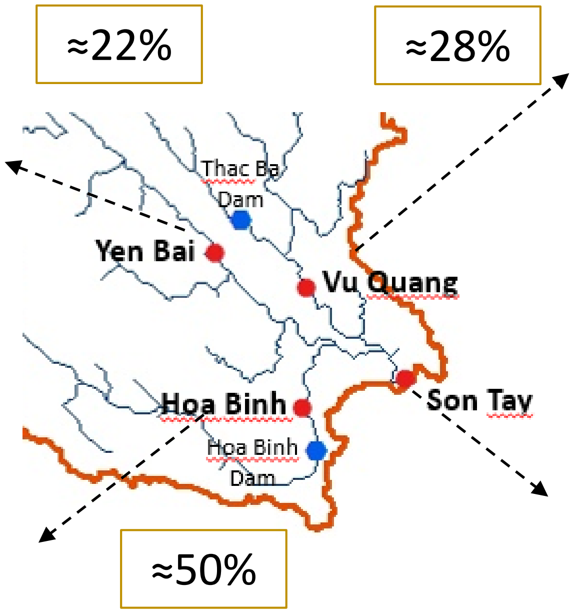
4. Result—Monthly Discharge

NSE=0.59, R^2=0.82

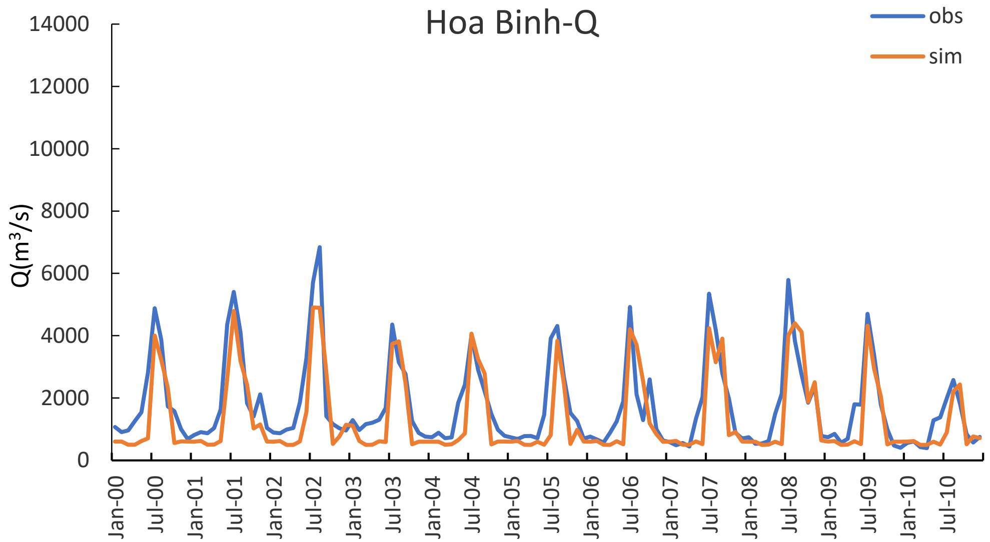


NSE=0.63, R^2=0.75

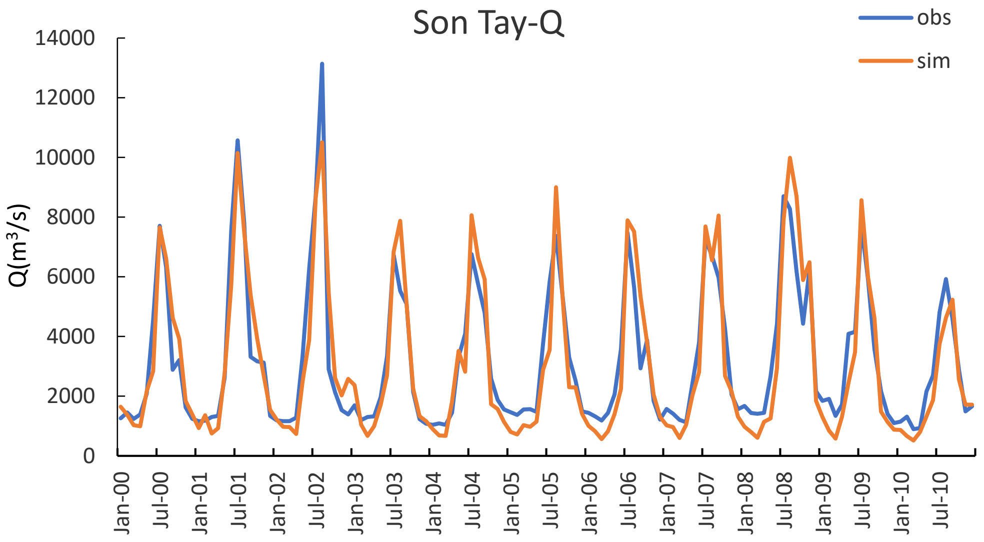




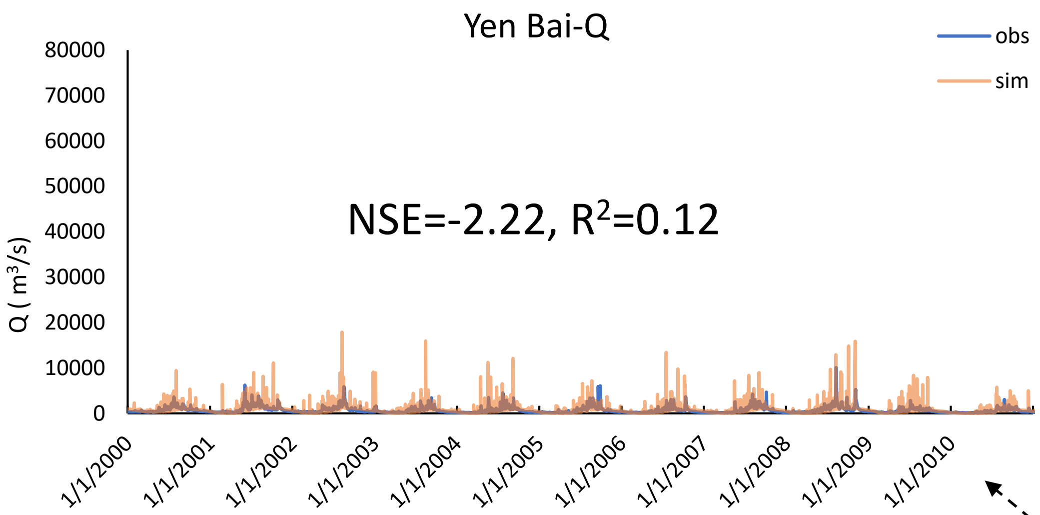
NSE=0.66, R^2=0.75

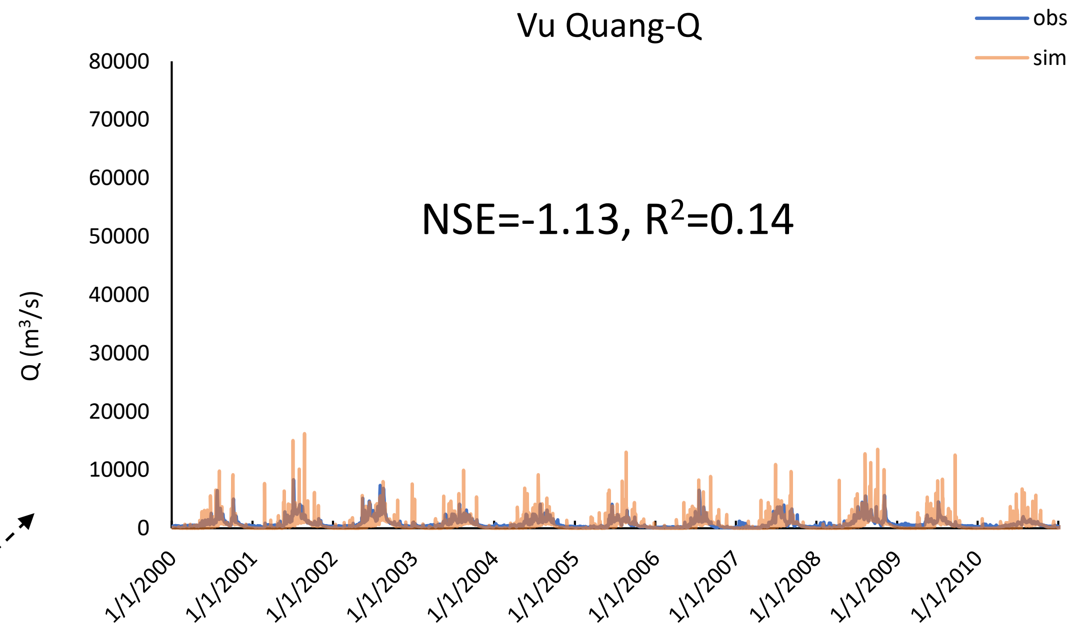


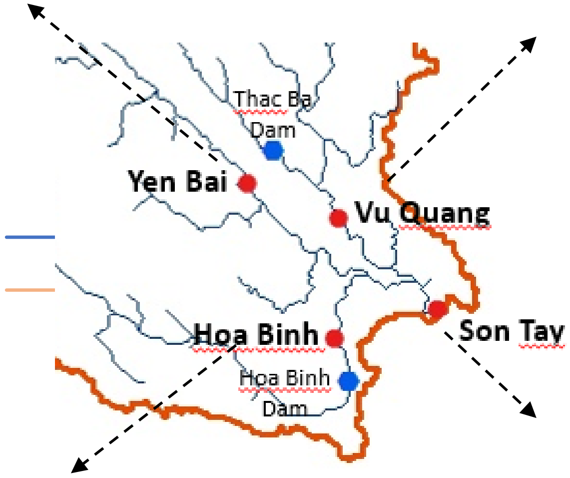
NSE=0.84, R^2=0.87

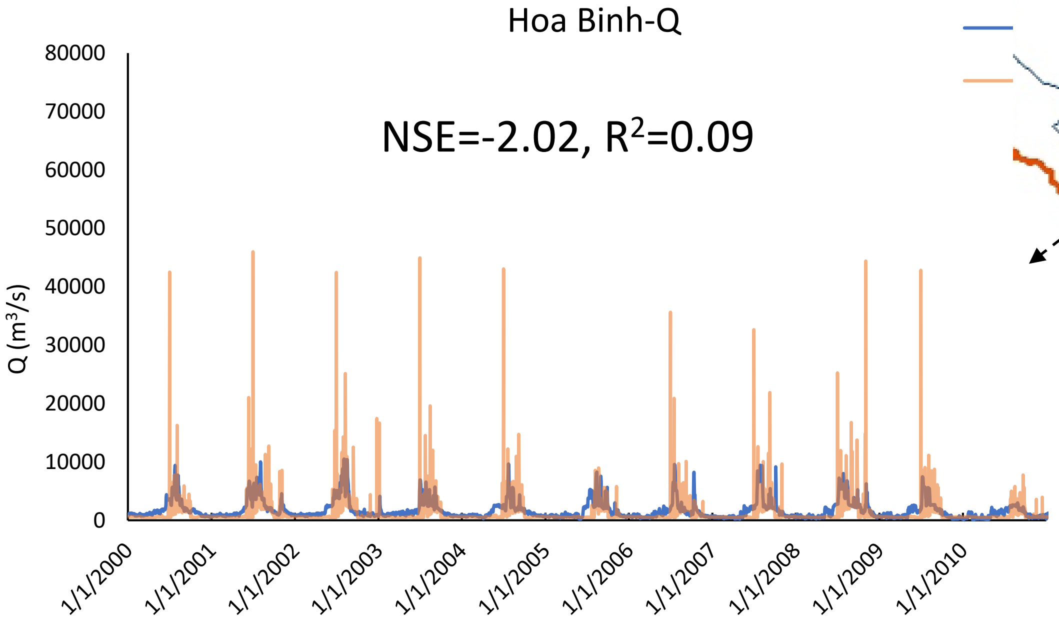


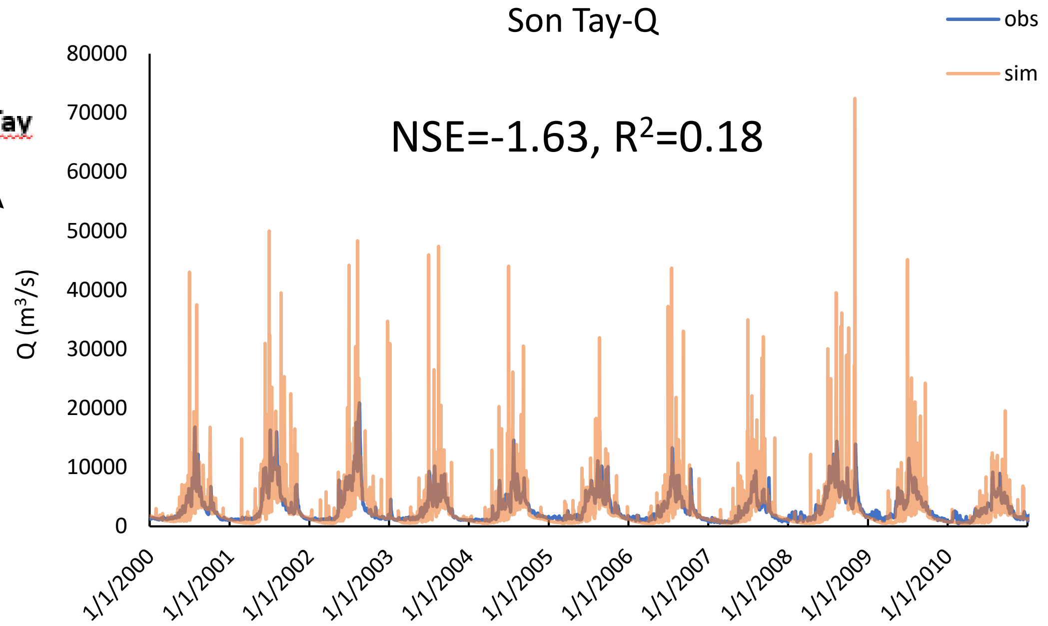
4. Results—Daily Discharge—Calibration in Progress





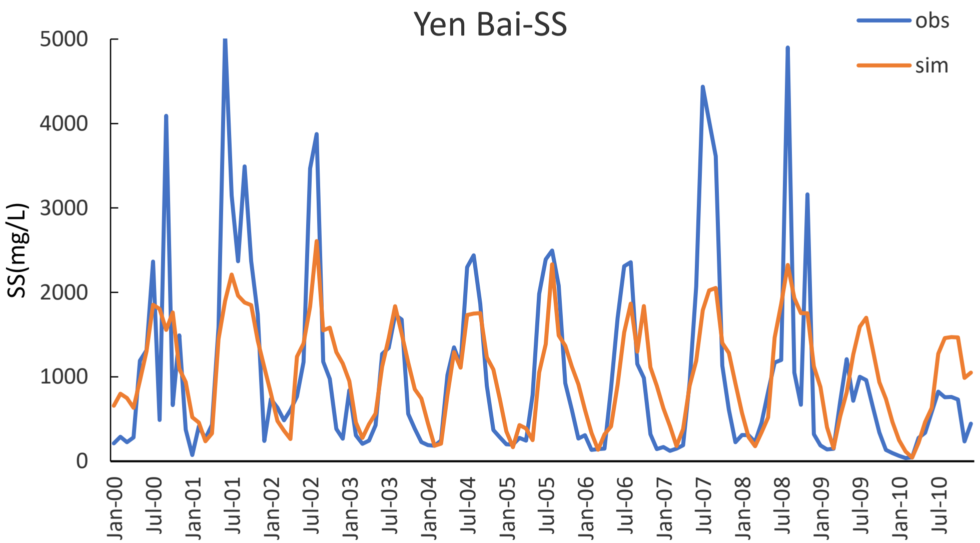




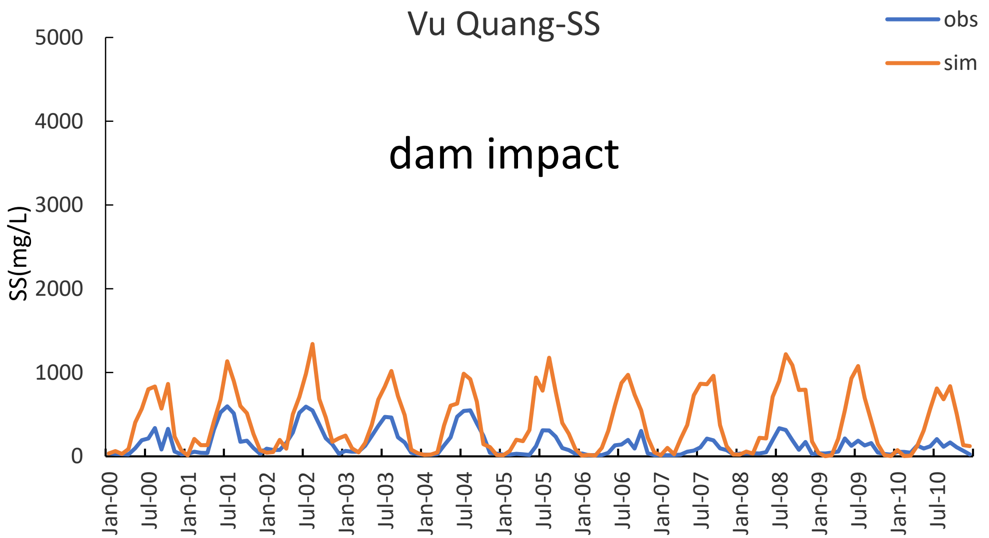


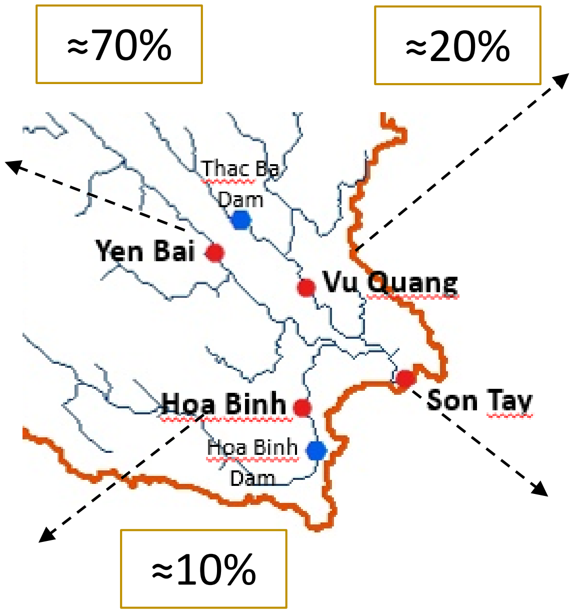
4. Result—Monthly Sediment Concentration

NSE=0.52, R^2=0.56

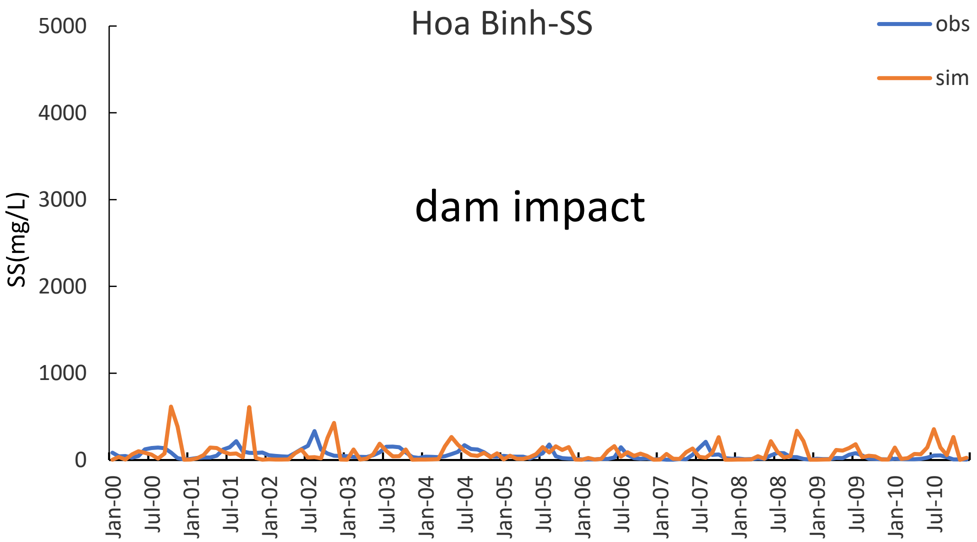


NSE=-5.15, R^2=0.57

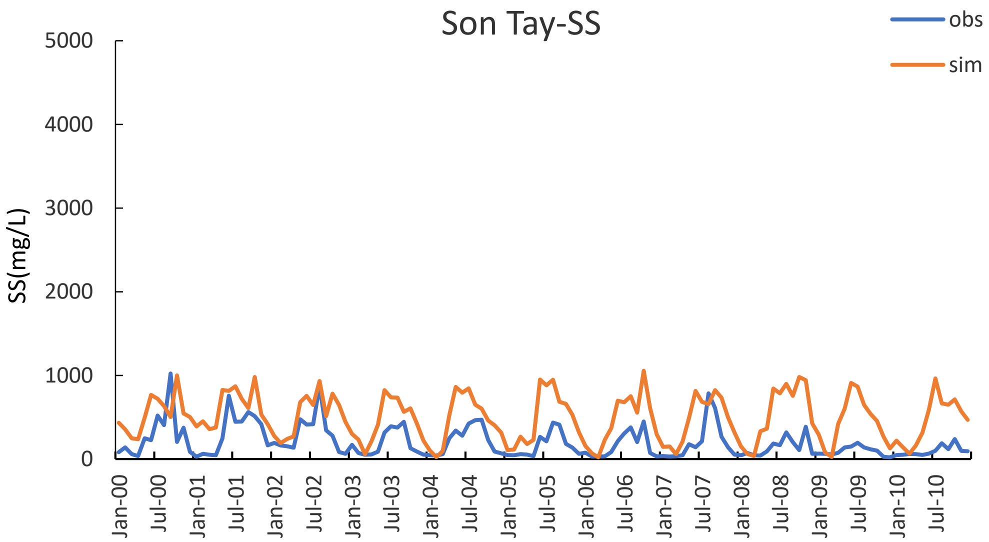




NSE=-3.77, R^2=0.01

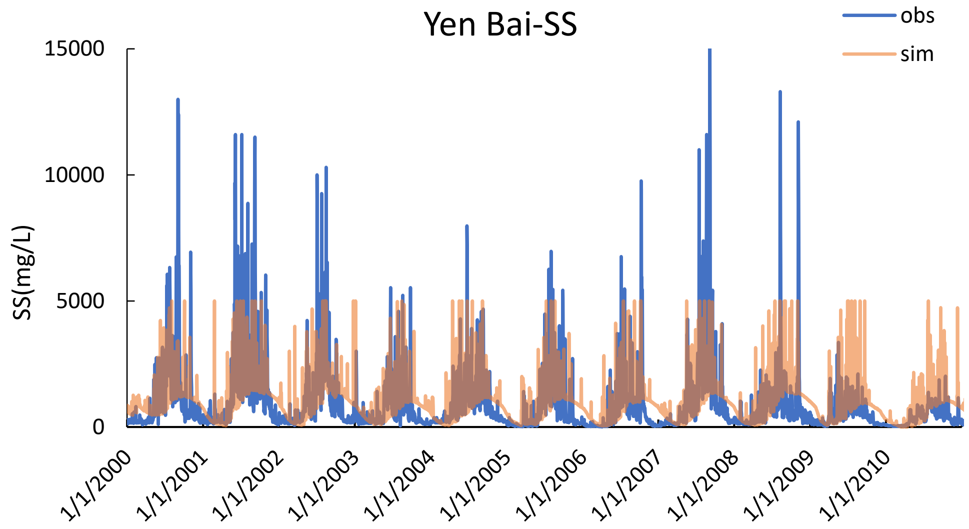


NSE=-2.85, R^2=0.38

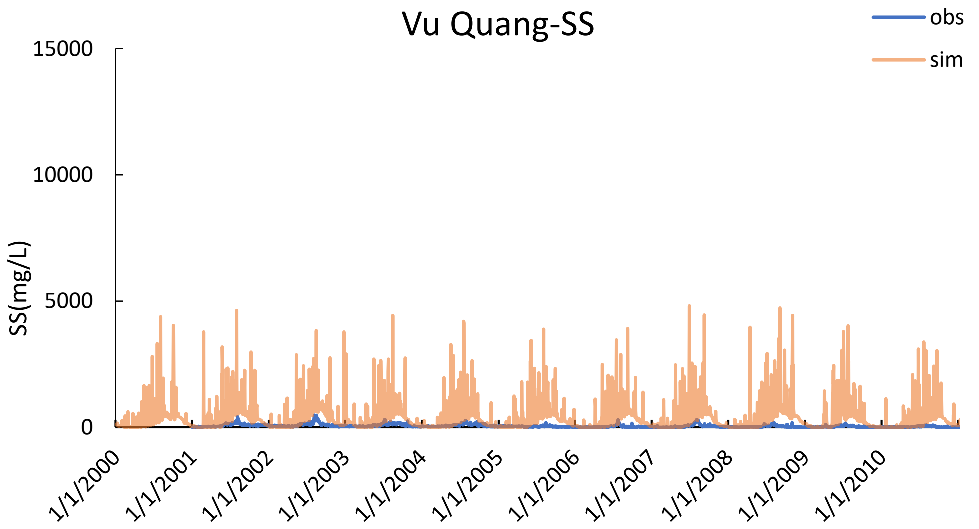


4. Results—Daily Sediment Concentration—Calibration in Progress

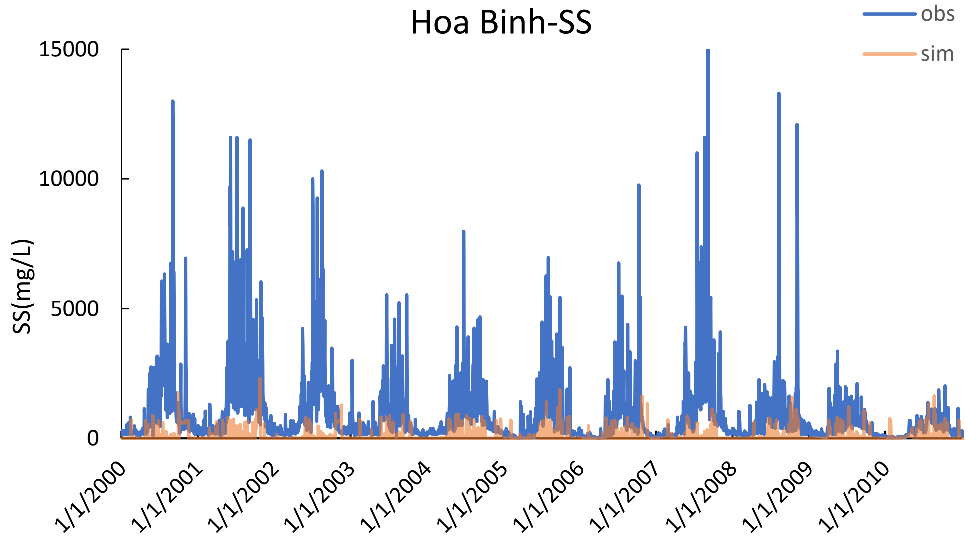
NSE=-0.10, R^2=0.12



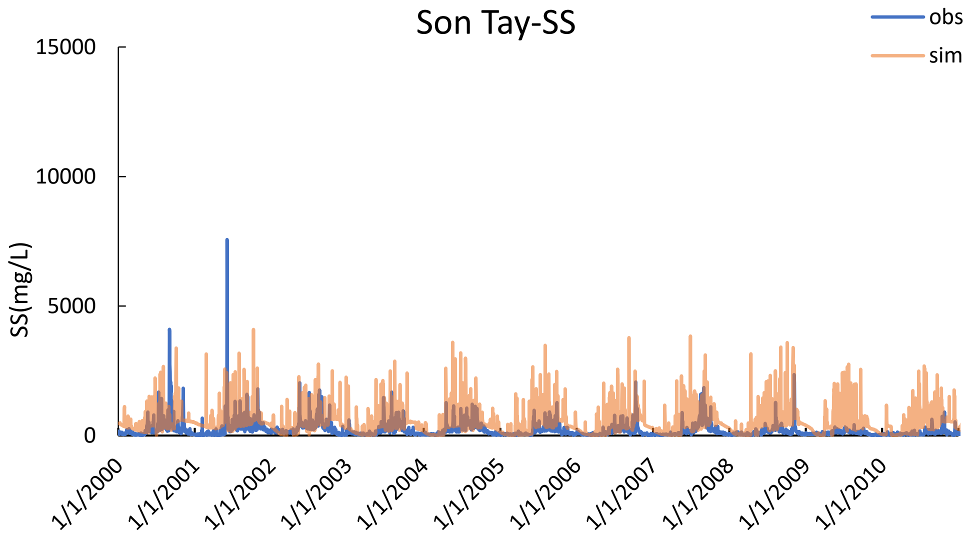
NSE=-0.29, R^2=0.01



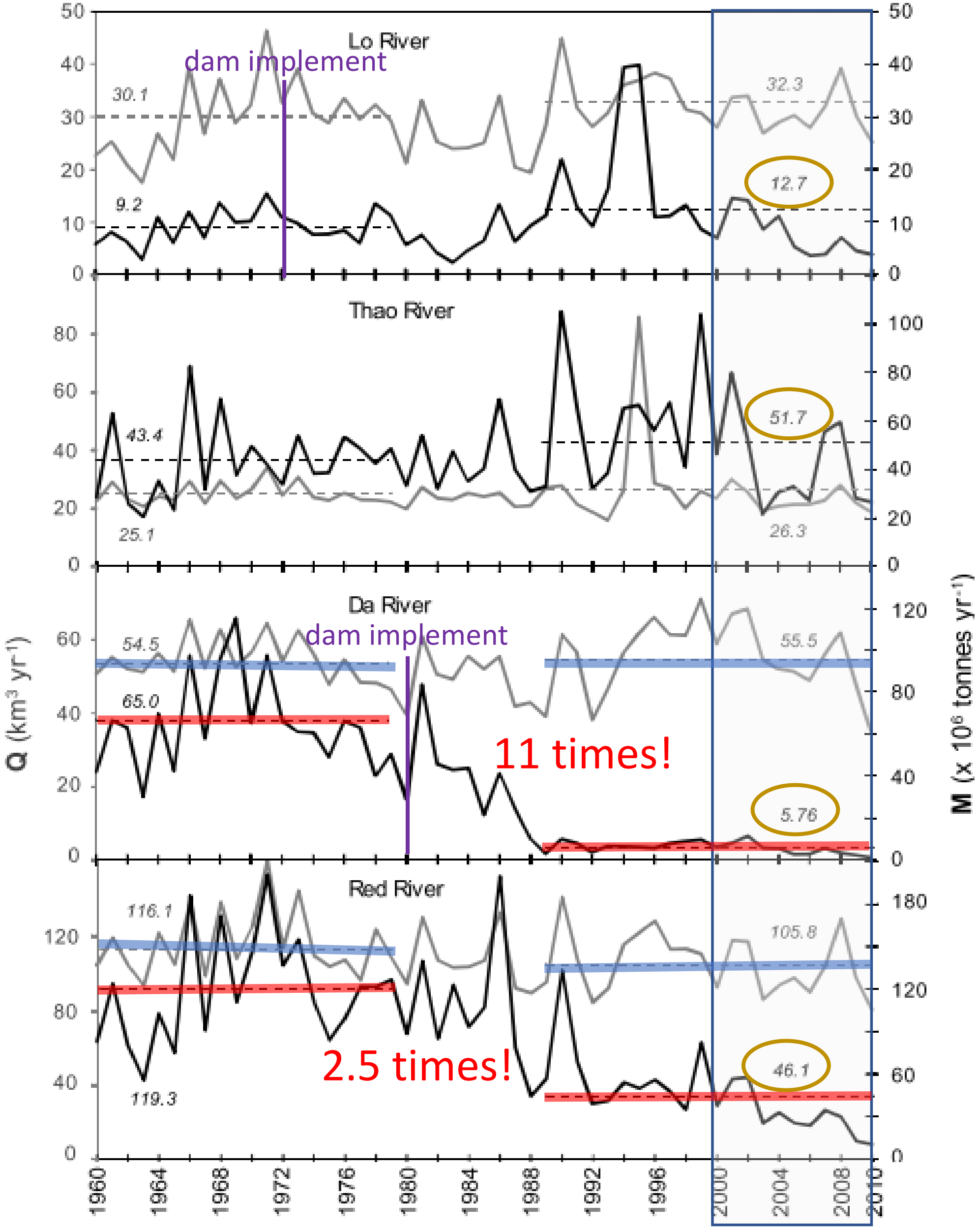
NSE=-0.30, R^2=0.01



NSE=-4.17, R^2=0.04



4. Results—Suspended Sediment Flux



Annual water and suspended sediment discharge (1960-2010)

(Picture extracted from Vinh et al., 2014)

simulation period: 2000-2010

Scenario: without dam

	simulation period: 2000-2010		Scenario: without dam
Vu Quang	14.8×10^6 ton/yr		
Yen Bai	39.6×10^6 ton/yr		
Hoa Binh	3.2×10^6 ton/yr	17 times!	55.1×10^6 ton/yr
Son Tay	63.1×10^6 ton/yr	1.8 times!	112.1×10^6 ton/yr

5. Methodology for Calculating DOC and POC

$$DOC = \frac{aQ}{b + Q}$$

DOC-mg/L; Q-mm/day

(Jonhson et Goody, 2011; Fabre et al., submitted)

Q_{obs}, DOC_{obs} ⇒ a, b ⇒ (Q_{sim}) DOC_{sim} ⇒ (Q_{obs}, Q_{sim}) $Flux_{obs}$, $Flux_{sim}$

$$\%POC = \frac{9.40}{SS - a} + b$$

%POC-the part of POC (mg C/L) in the SS;
SS-mg/L

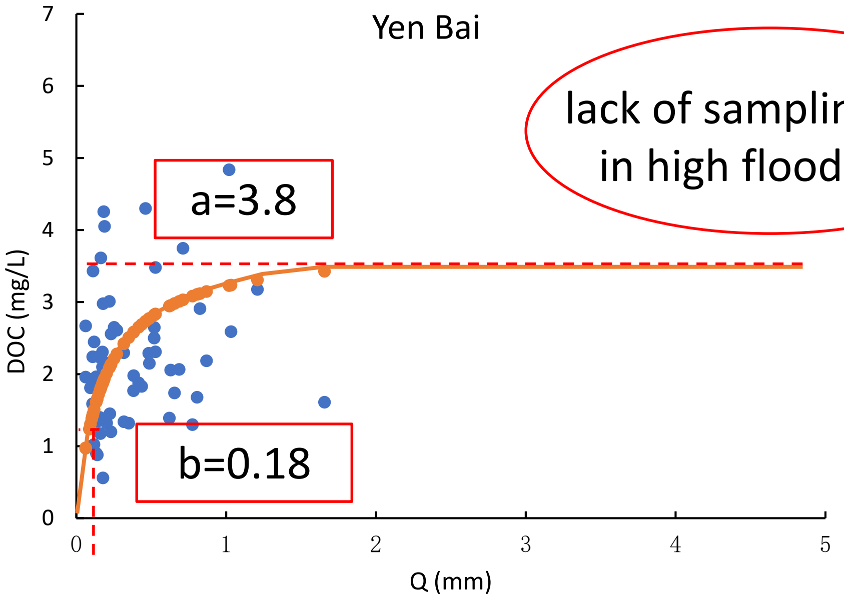
(Boithias et al., 2014; Fabre et al., submitted)

SS_{obs}, POC_{obs} ⇒ a, b ⇒ (SS_{sim}) POC_{sim} ⇒ (SS_{sim}) $Flux_{sim}$

DOC : Dissolved organic carbon

POC : Particulate Organic Carbon

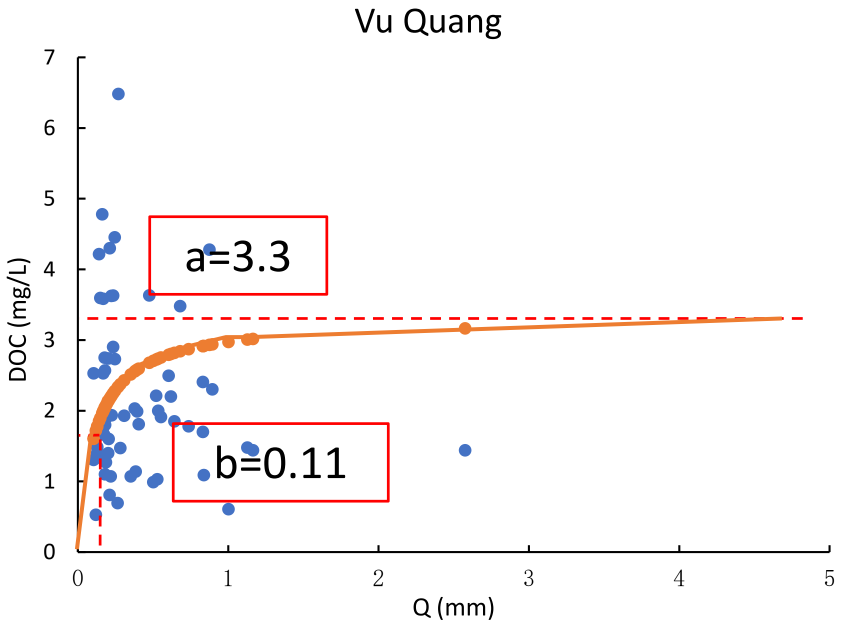
6. Results—DOC Concentration

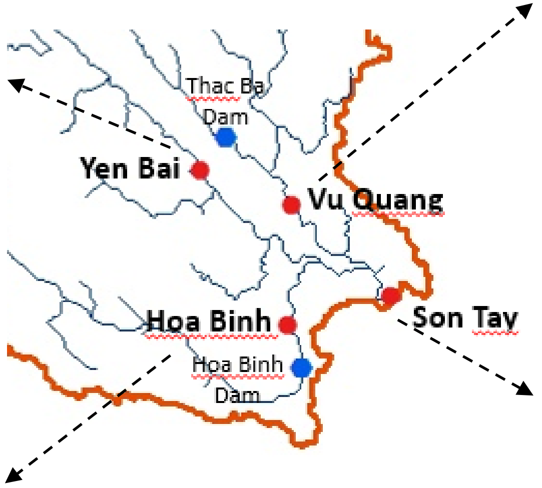


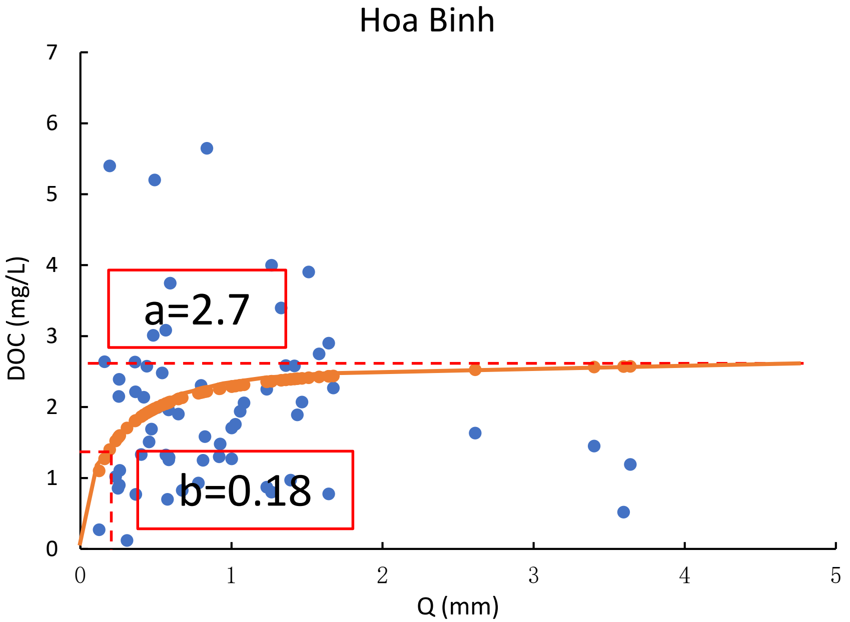
$$DOC = \frac{aQ}{b + Q}$$

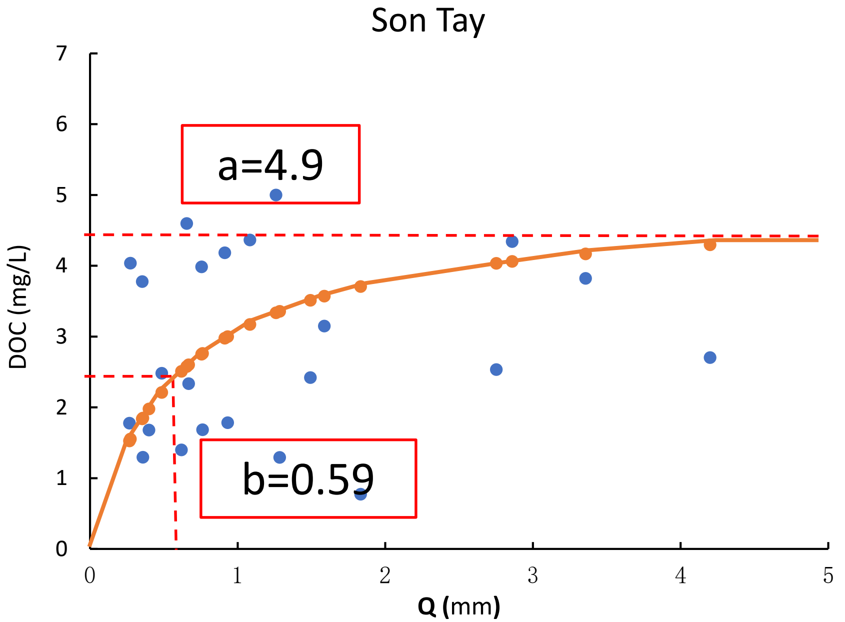
DOC-mg/L; Q-mm/day

(Jonhson et Goody, 2011; Fabre et al., submitted)



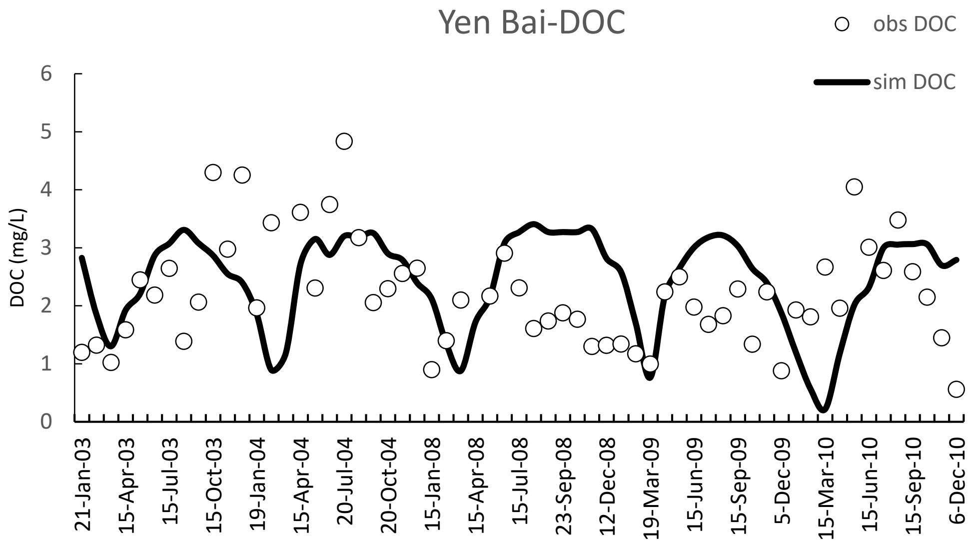




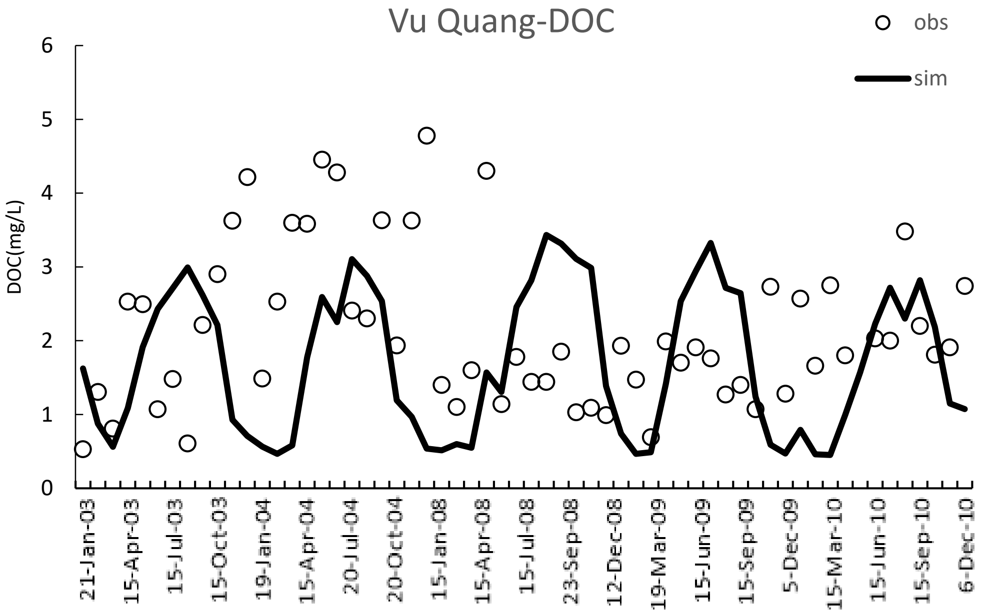


6. Results—DOC Concentration—In Progress

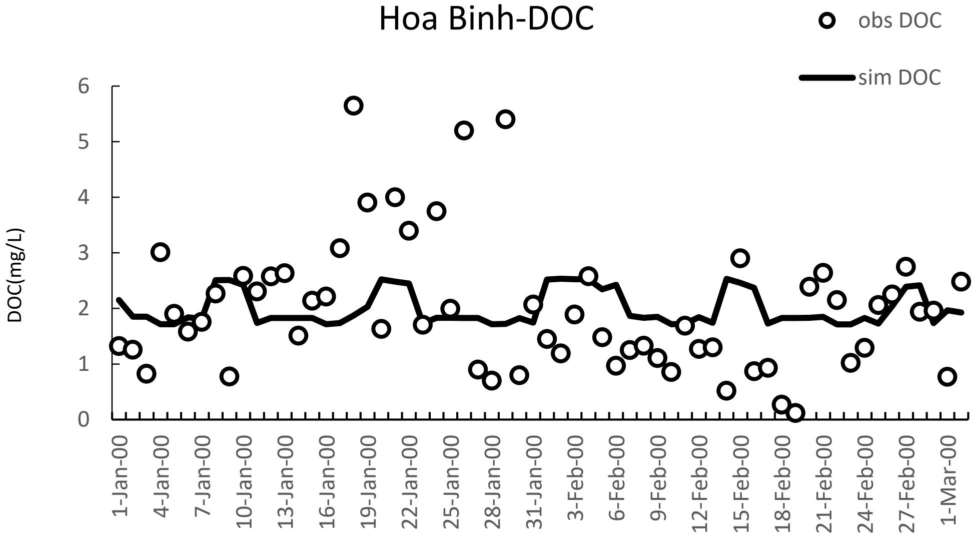
NSE=-0.42, R^2=0.0005



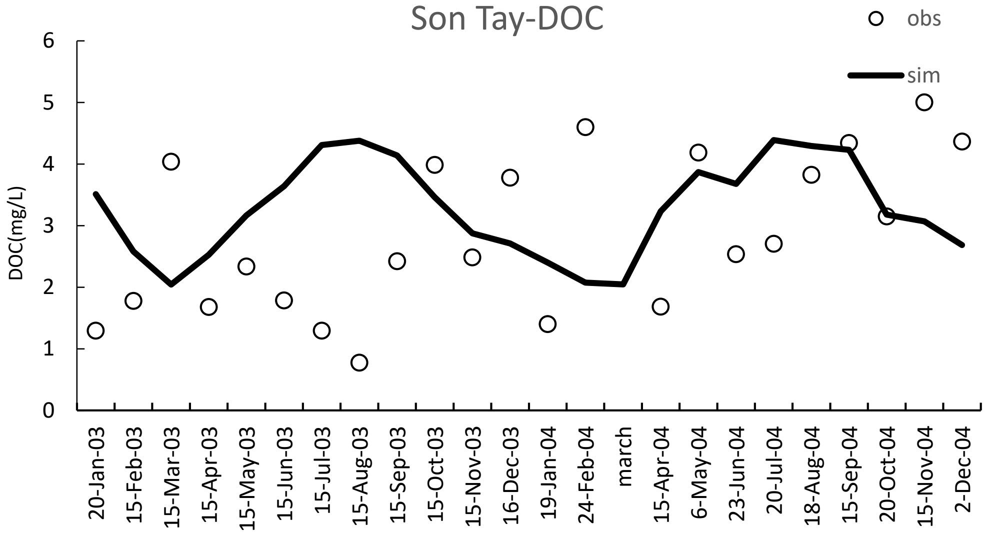
NSE=-0.33, R^2=0.0008



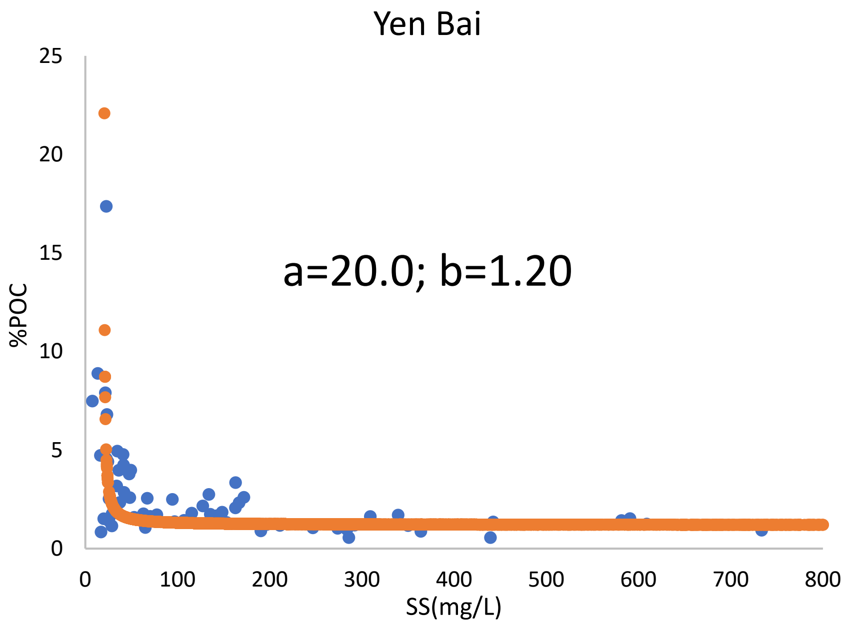
NSE=-0.07, R^2=0.00005



NSE=-0.74, R^2=0.04



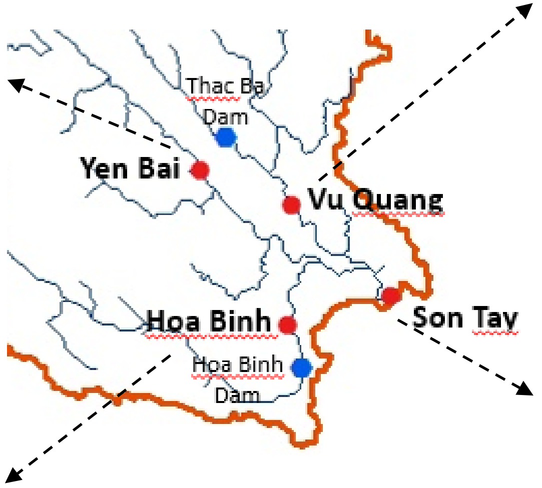
6. Results—POC Concentration—In Progress

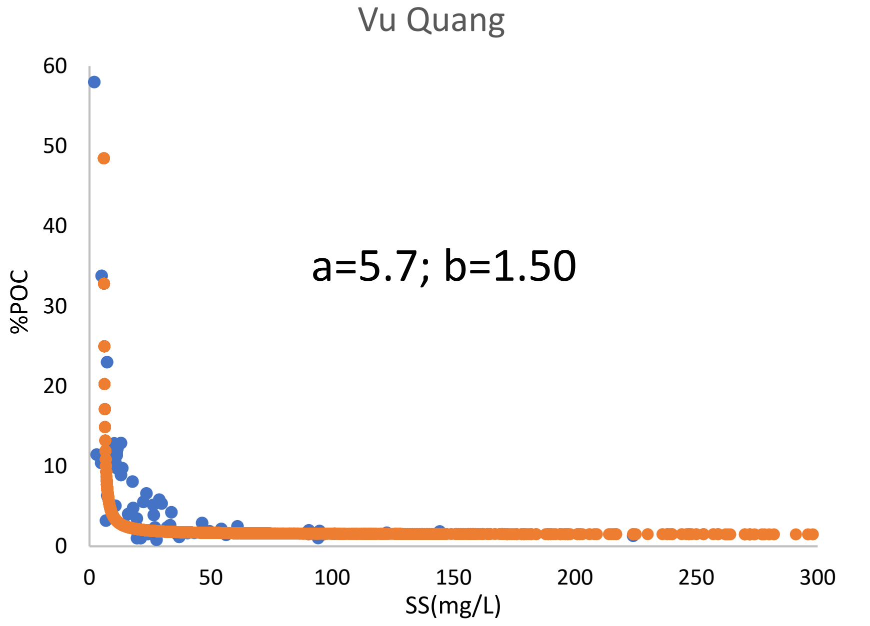


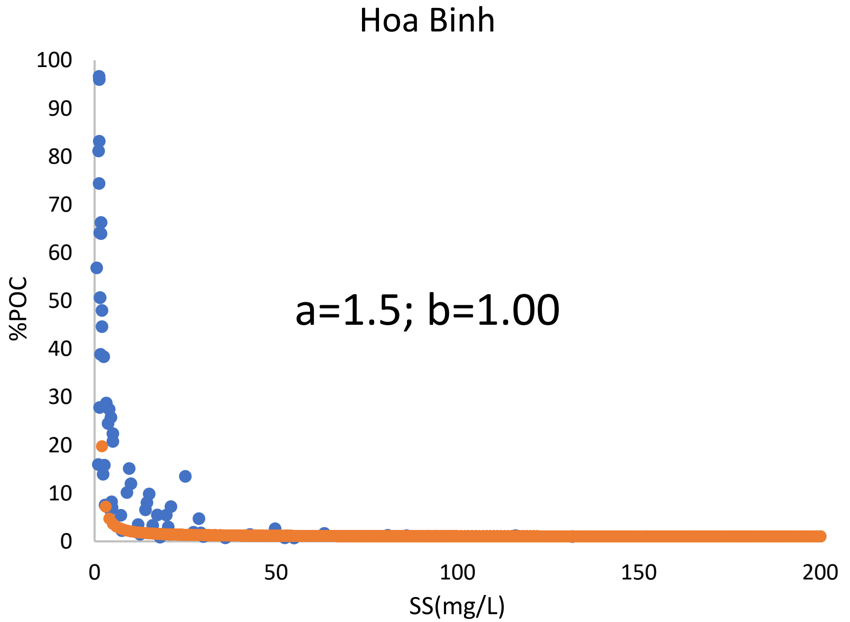
$$\%\text{POC} = \frac{9.40}{SS - a} + b$$

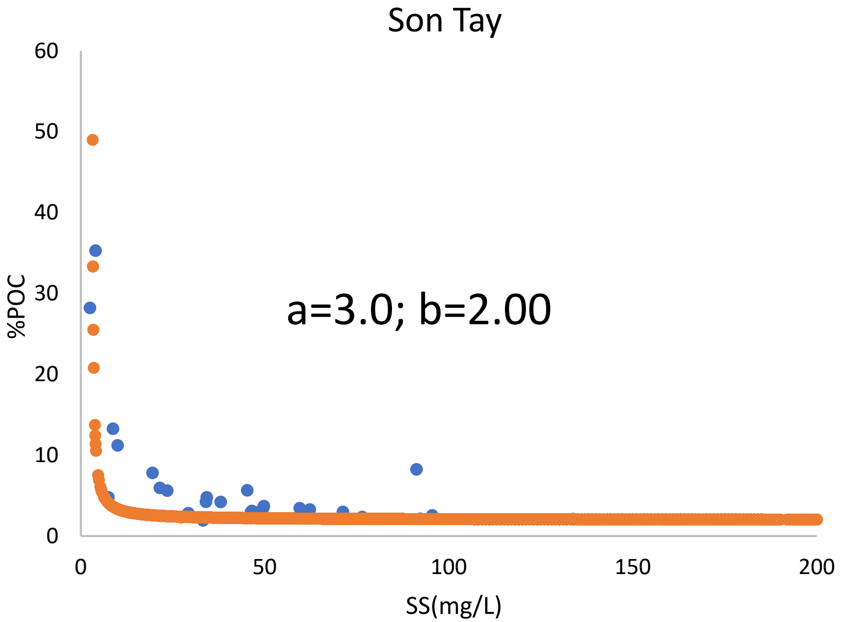
%POC-the part of POC (mg C/L) in the SS;
SS-mg/L

(Boithias et al., 2014; Fabre et al., submitted)

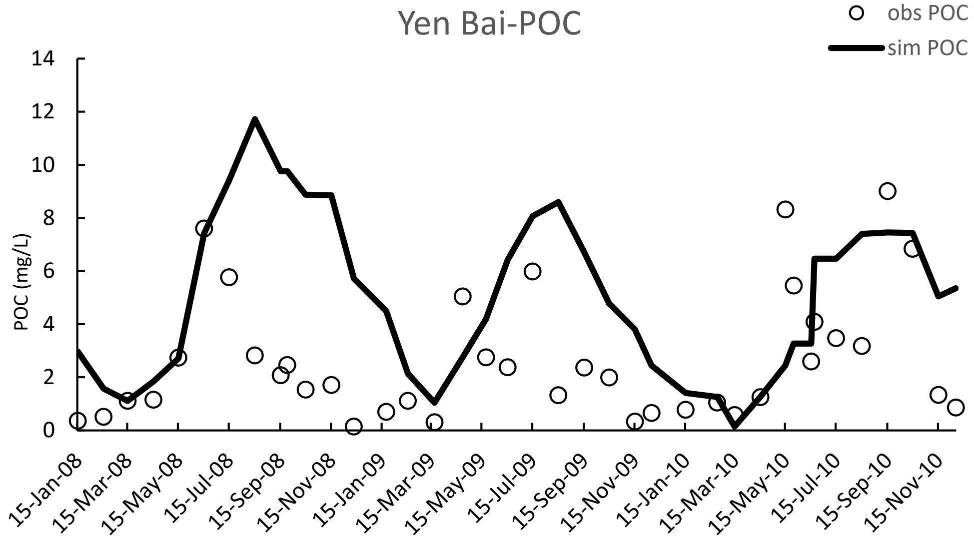


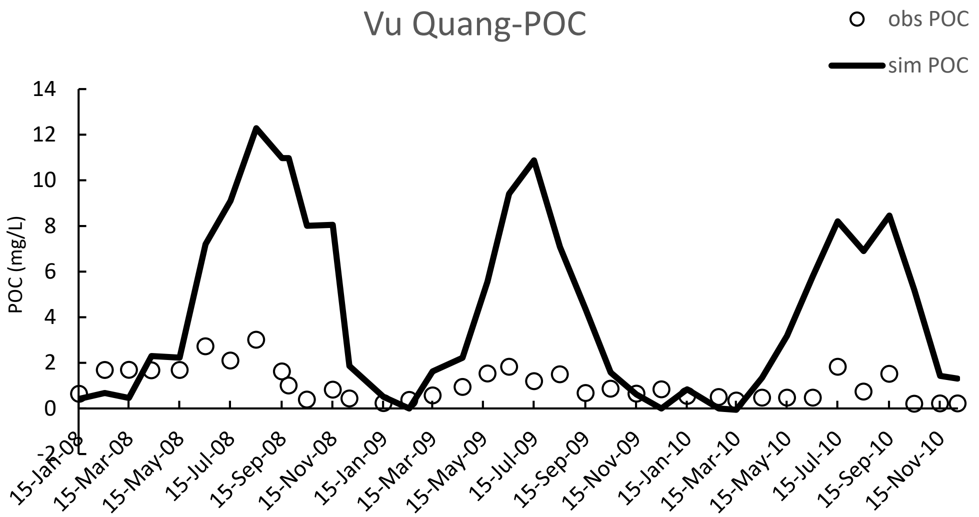


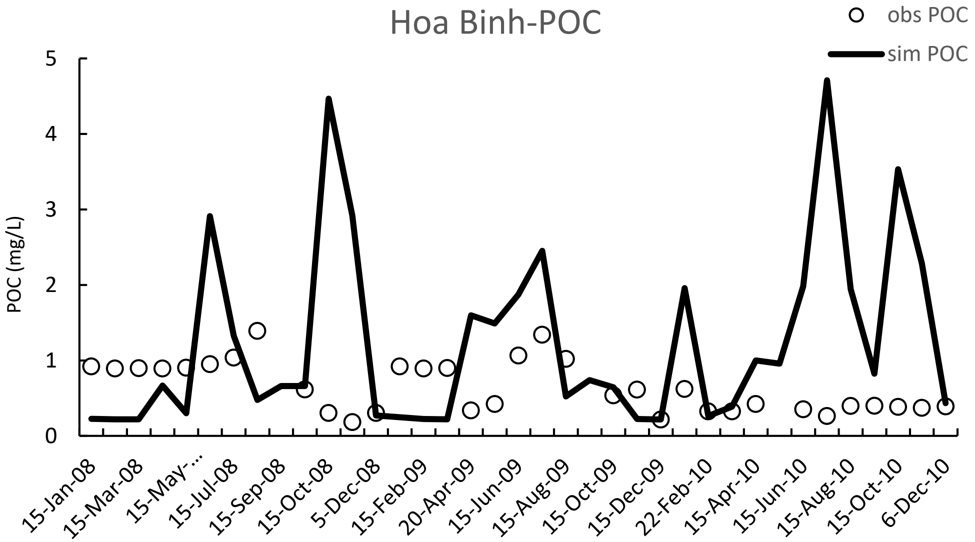




6. Results—POC Concentration







7. Conclusions and Perspectives

- SWAT presents a good simulation on monthly scale, and better simulation on discharge than on sediment concentration. This shows the big impact of the dam on sediment. And this conclusion can also be proved by the scenario simulation result.

- POC shows a clear tendency and fits the equation well while DOC doesn’t. This is might due to the lack of sampling data during high discharge days.

- In order to better simulate the DOC and POC, it’s very necessary to work on daily scale as monthly scale might ignore the dynamic changes from day to day. And now we are in progress to get a good simulation of Q and SS on daily scale.


Thanks for Your Attention

Questions
Suggestion

4. Methodology

- **Parameter Setting**

Parameter	Input File	Definition	Range	Calibrated Value
PRF	.BSN	Peak rate adjustment factor for sediment routing in the main channel	0-2	2
SPCON	.BSN	Linear parameter for calculating the maximum amount of sediment that can be reentrained during channel sediment routing	0.0001-0.01	0.0002
SPEXP	.BSN	Exponent parameter for calculating sediment reentrained in channel sediment routing	1-2	2
ALPHA_BF	.gw	Baseflow alpha factor (1/days)	0-1	0.015
GW_REVAP	.gw	Groundwater "revap" coefficient	0.02-0.20	0.15
REVAPMN	.gw	Threshold depth of water in the shallow aquifer for “revap” or percolation to the deep aquifer to occur (mm H_2O)	0-1000	650
RCHGR_DP	.gw	Deep aquifer percolation fraction	0.0-1.0	0.01
GWQMN	.gw	Threshold depth of water in the shallow aquifer required for return flow to occur (mm H_2O).	0-5000	800
GW_DELAY	.gw	GW_DELAY Groundwater delay time (days).	0-500	40
CN2	.mgt	Initial SCS runoff curve number for moisture condition II	35-98	*0.95
SOL_AWC	.sol	Available water capacity of the soil layer (mm H_2O/mm soil)	0-1	*1.2
CH_COV1	.rte	The channel erodibility factor	-0.05-0.6	0.6
CH_COV2	.rte	Channel cover factor	-0.001-1	1