

Comparative assessment of SWAT-Twn model performance for simulating erosion and sediment transport in two distinct basins in Taiwan

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Introduction

- Taiwan is on the orogenic belt where the plate collides. The plate movement of the inner force lifts the ground to form mountains and the erosion of external forces such as earthquakes, typhoons, heavy rain. Forming special geology and topography in Taiwan. From July to September each year, heavy rain and typhoon provide abundant power for river sediment transport. Therefore, it is necessary to find a suitable sediment transport equation for Taiwan.

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- Lin(2000), Chang(2005), Chen and Chang(2007) pointed out that the heavy rainfall and flow produced by typhoon or torrential rain is the main transporting force of the sediment of the river.
 - Lin(2010) analyzed the flow and sediment data of thirteen major rivers in Taiwan. The results show that there is a highly positive correlation between sediment and flow.
 - Lu(2018) pointed out that SWAT-Twn is suitable for upstream rivers, and it can be used to simulate downstream sediment transport with the Yang equation (CH_EQN=4) 、 CH_BNK_D50 、 CH_BED_D50. This combination allows a better simulation of downstream sediment transport of the river.

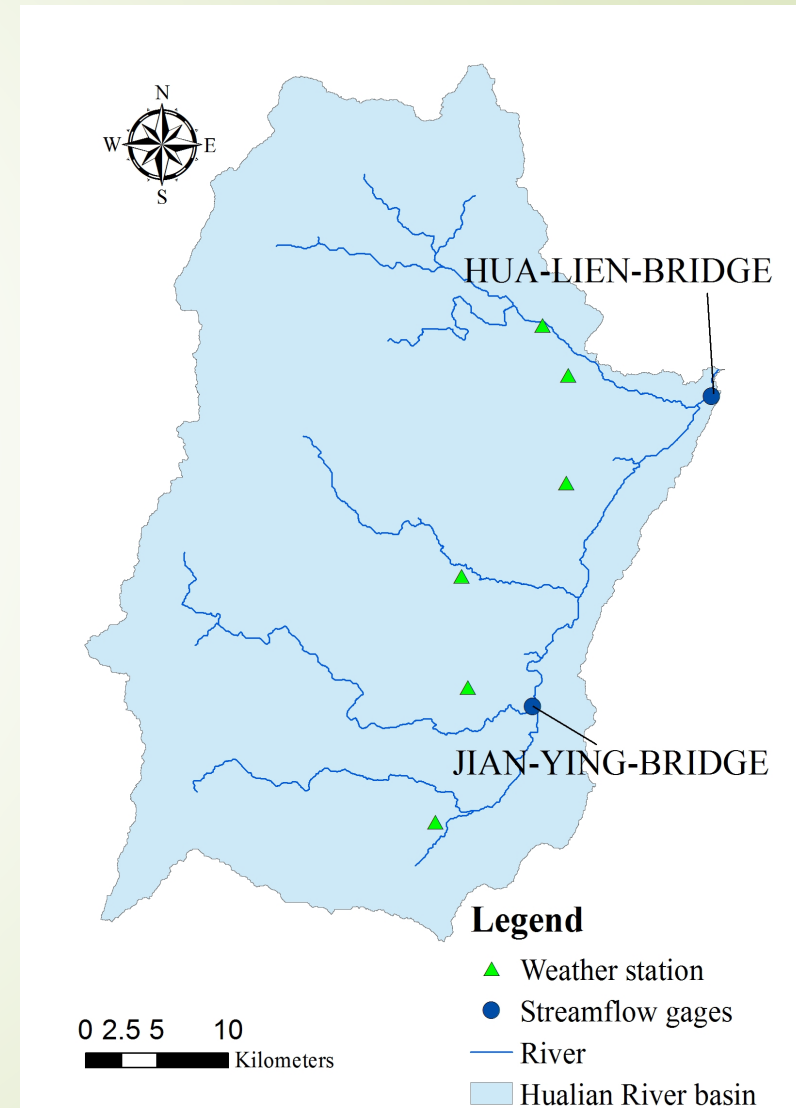
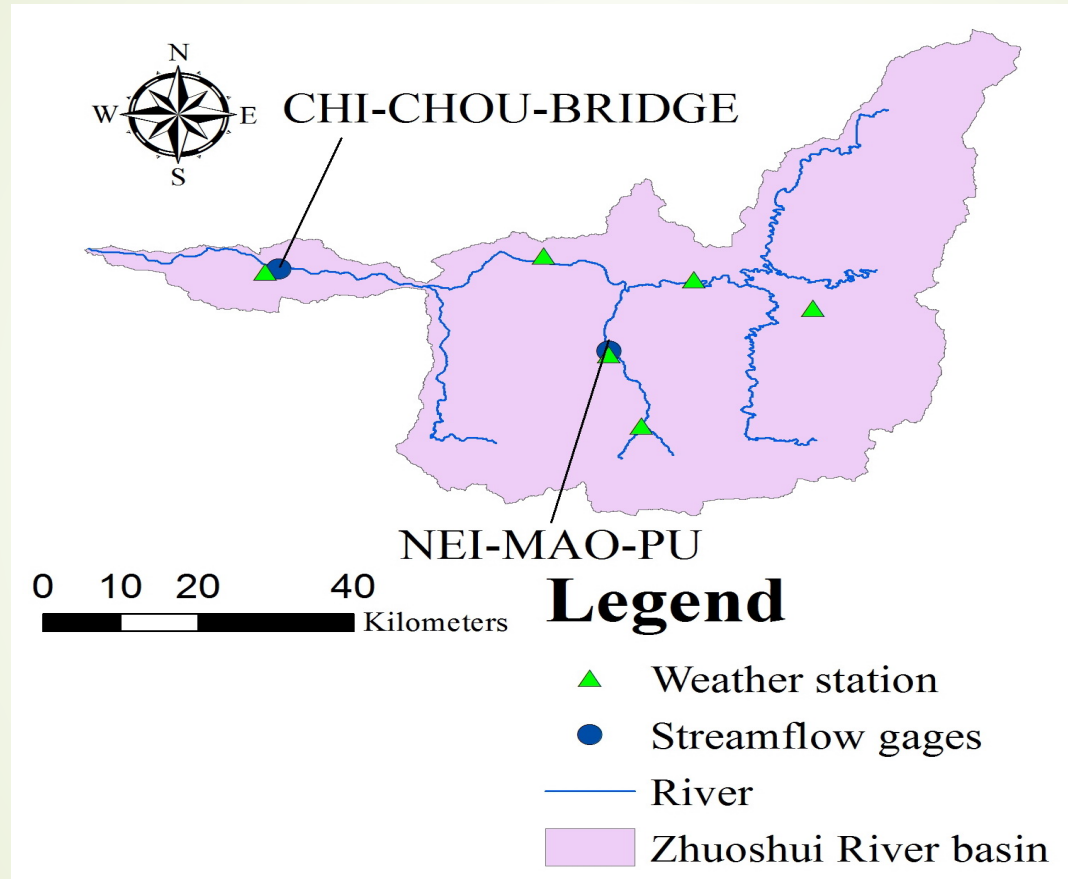
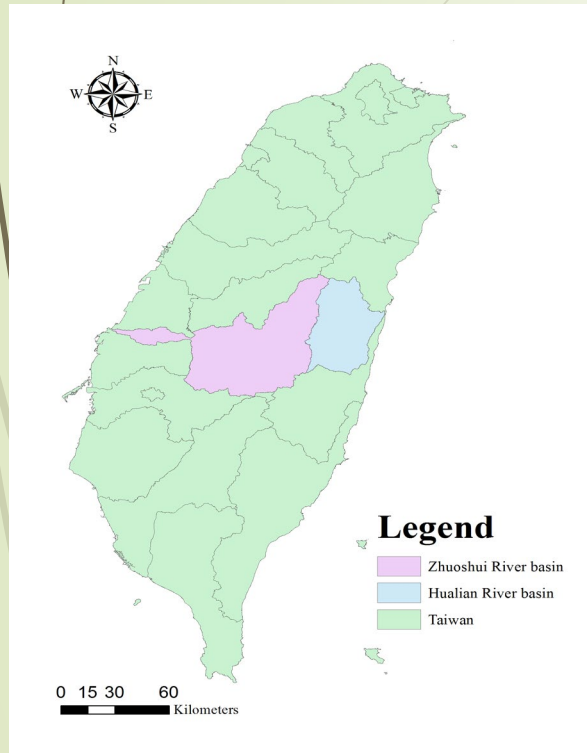
Objectives

- We used the SWAT-Twn model that it completed by Chih-Mei Lu(2018) to simulate the sediment transport of the Zhuoshui River Basin (ZRB) and the Hualian River Basin (HRB), and compared the results of the sediment transport simulation with the SWAT-2012 version.
- It evaluates the suitability of the SWAT-Twn model for sediment transport in the Zhuoshui River Basin and the Hualian River Basin.

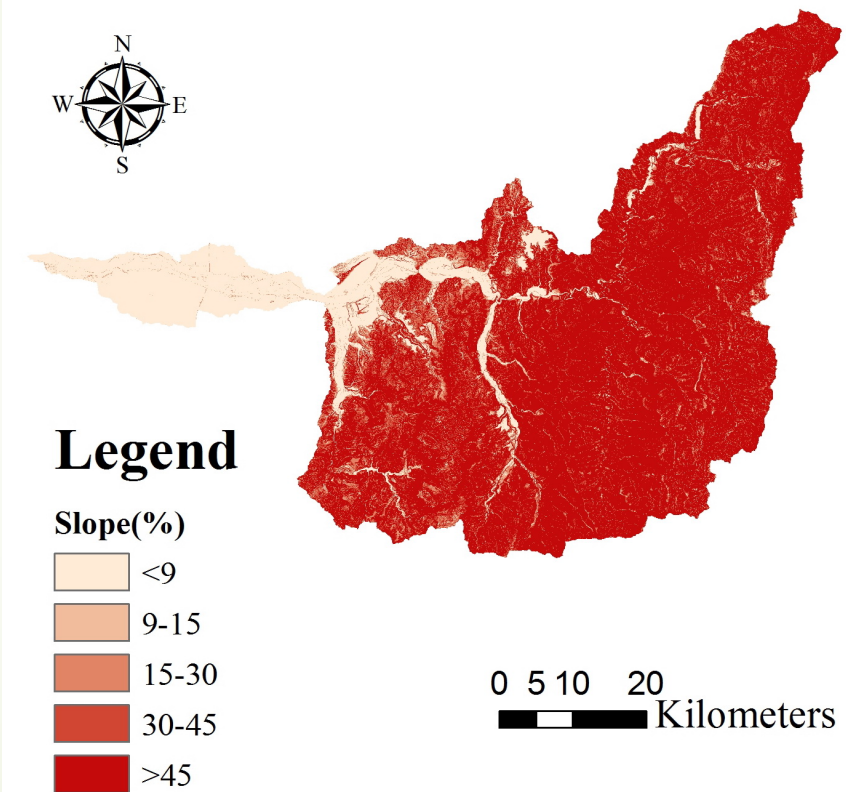
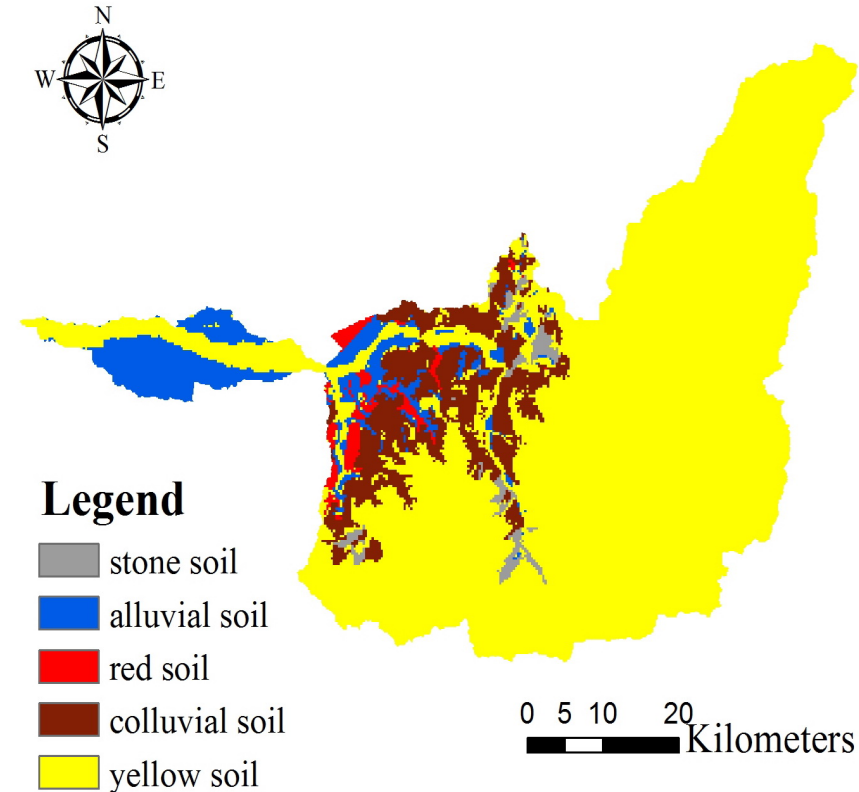
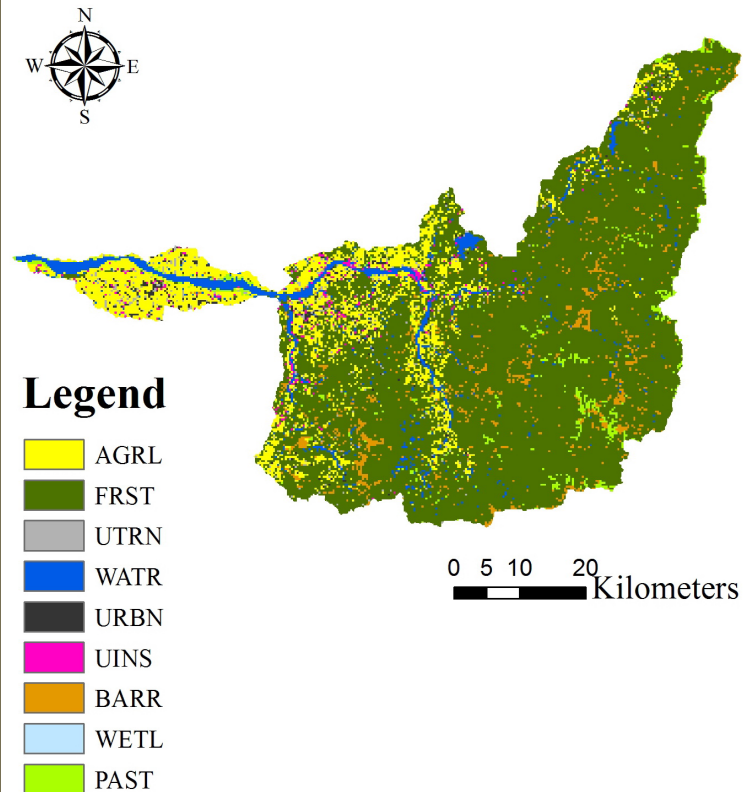
Study area

Zhuoshui River Basin(ZRB) Hualian River Basin (HRB)

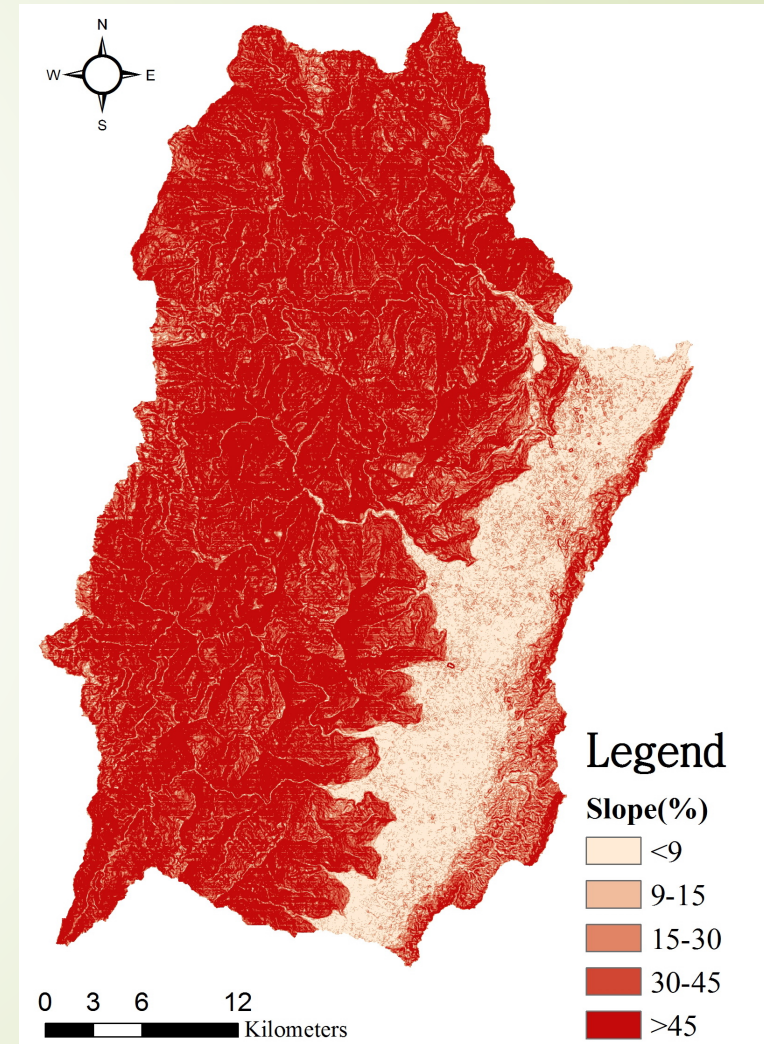
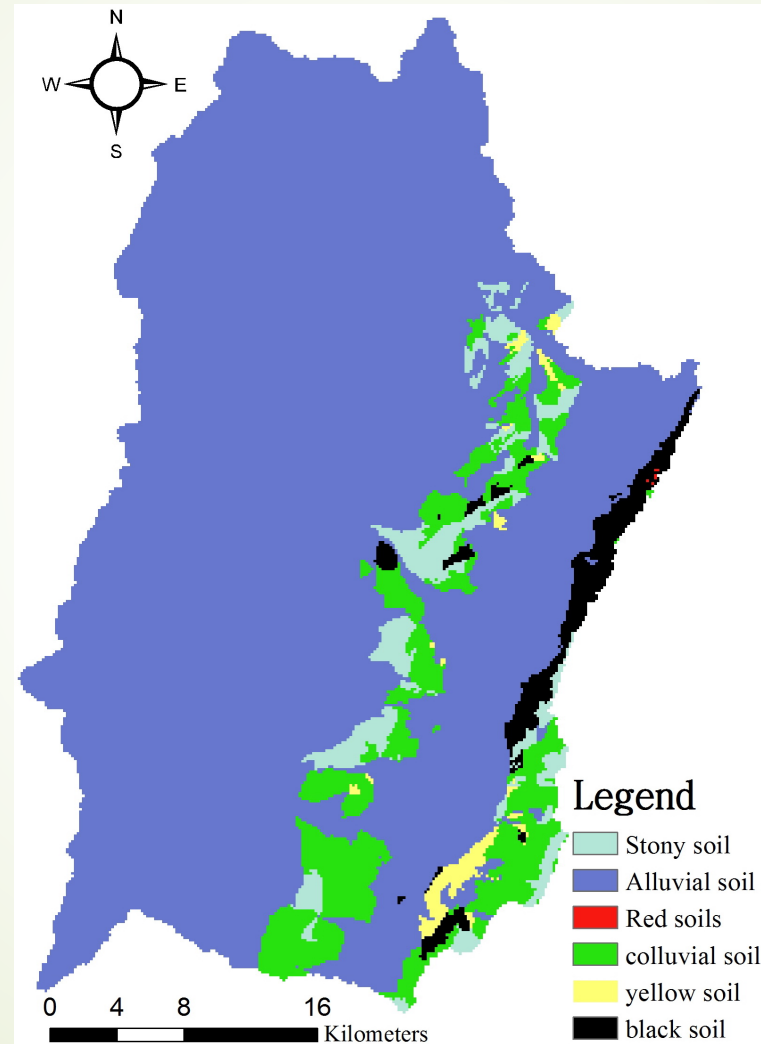
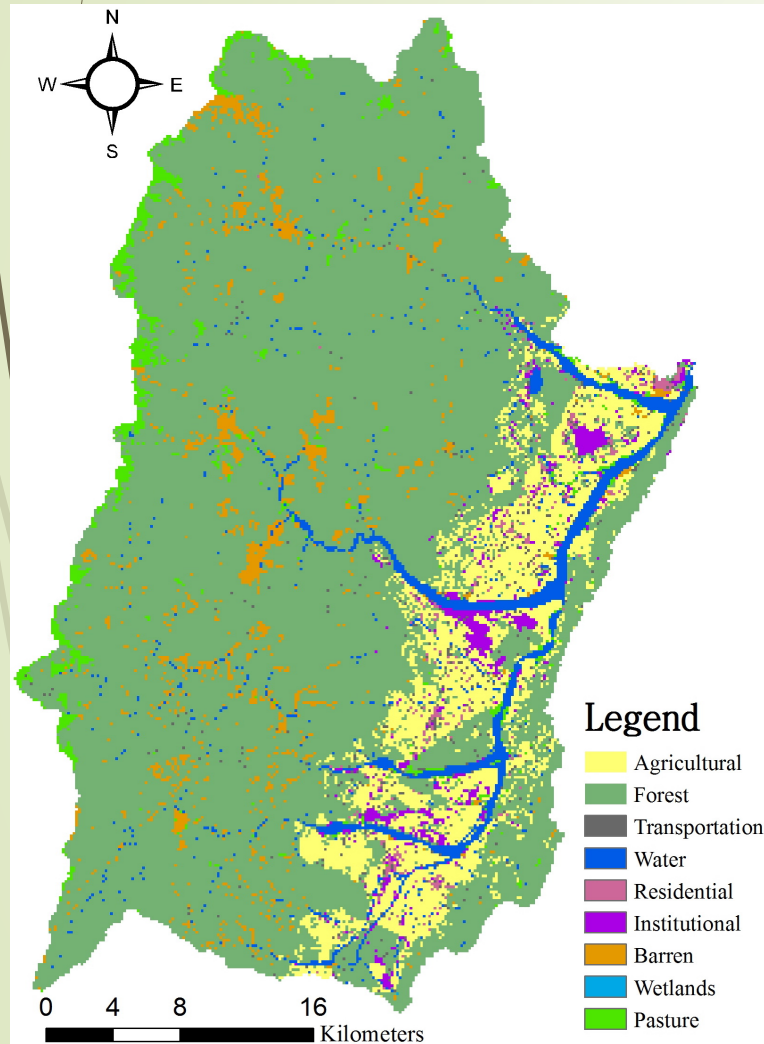
Taiwan



Land use, soil and slope map of ZRB



Land use, soil and slope map of HRB



Study materials and methods

- We use SWAT-Twn and Taiwan Universal Soil Loss Equation (TUSLE) that it was revised from Universal Soil Loss Equation (USLE) by Chen *et al.*(2009).
- Model version :

Version	Sediment transport equation
SWAT-2012	The sediment transport equation is only applicable to the USA.
SWAT-Twn	Establishing the debris volume estimate equation and factor S、LS.

SWAT-Twn also integrated the landslide simulation. When the daily rainfall exceeds 350mm,the landslide simulation will be activated.

TUSLE-Slope steepness factor (S)

- Topographic factor (LS) : The Wischmeier and Smith (1978) equation would overestimate LS factor in area of steeper slope.

Wischmeier and Smith (1978) equation:

$$LS = \left(\frac{X}{22.13} \right)^m (0.0654 + 4.56 \sin \theta + 65.4 \sin^2 \theta)$$

- Many studies indicated that Wischmeier and Smith (1978) topography factor equation could only suitable for the slope form 0.1% to 18%, while the S factor equation revised by McCool *et al.* (1987) could more reasonably predict soil loss at steep topography.

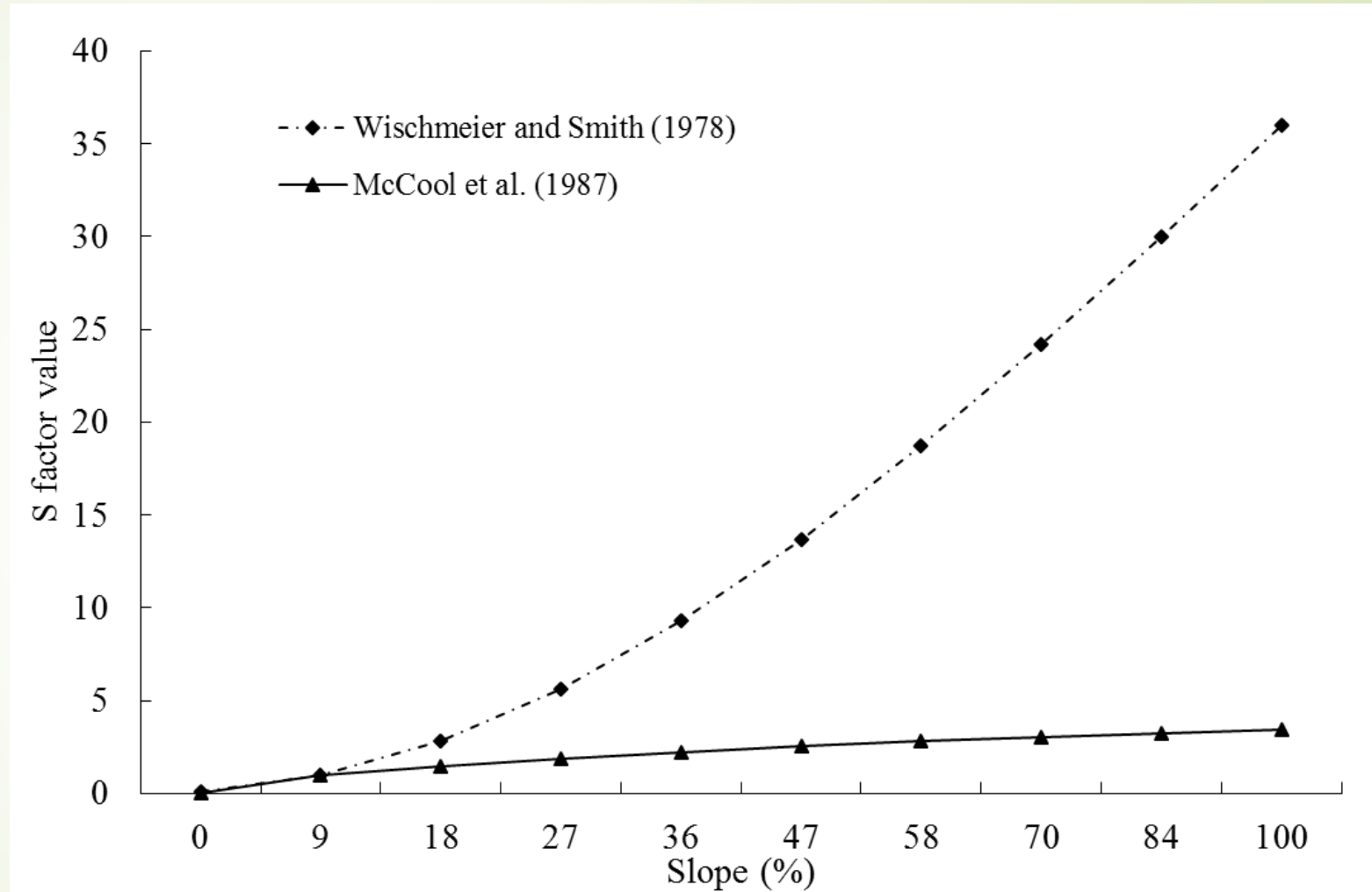
McCool *et al.* (1987) equation:

$$S = 10.8 \sin \theta + 0.03, \quad \theta < 9\%$$

$$S = \left(\frac{\sin \theta}{0.0896} \right)^{0.6}, \quad \theta \geq 9\%$$

TUSLE-Slope steepness factor (S)

Thus, the S factor estimated by McCool *et al.* (1987) equation is suggested to be more suitable for steep topography area.



TUSLE-Slope length factor (L)

➡ Slope length factor (L):

Wischmeier and Smith (1978) equation:

$$L = \left(\frac{X}{22.13} \right)^m$$

where X = slope length (m), m = exponential factor.

➡ In MUSLE: $m = 0.6 \times (1 - e^{-35.835 \cdot S})$

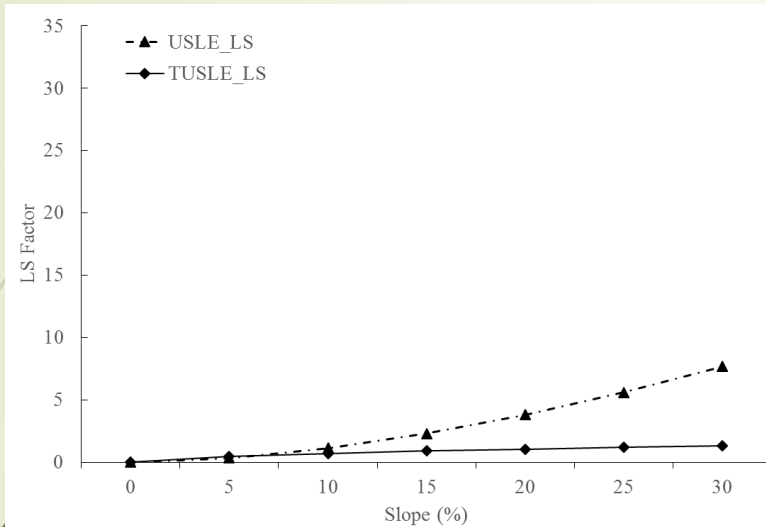
where s is the slope of HRU

➡ In TUSLE, $m = 0.5$ for the average slope greater than 5%; $m=0.4$ for the average slope between 3%-5%; $m=0.3$ for slope between 1%-3%; $m=0.2$ for slope less than 1%.

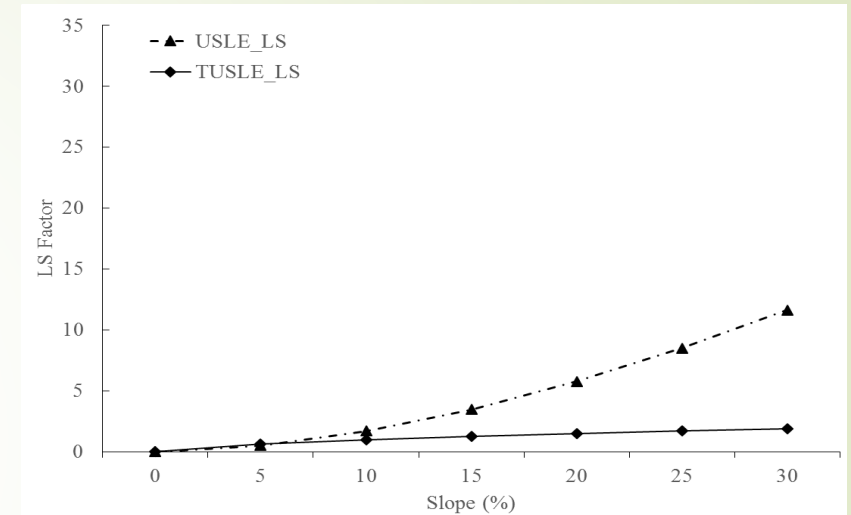
TUSLE-Topography factor (LS)

12

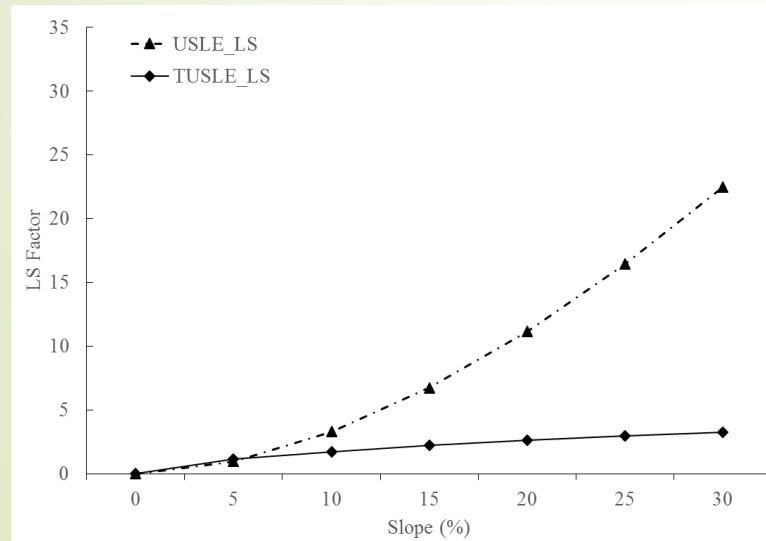
- Slope Length = 5 m



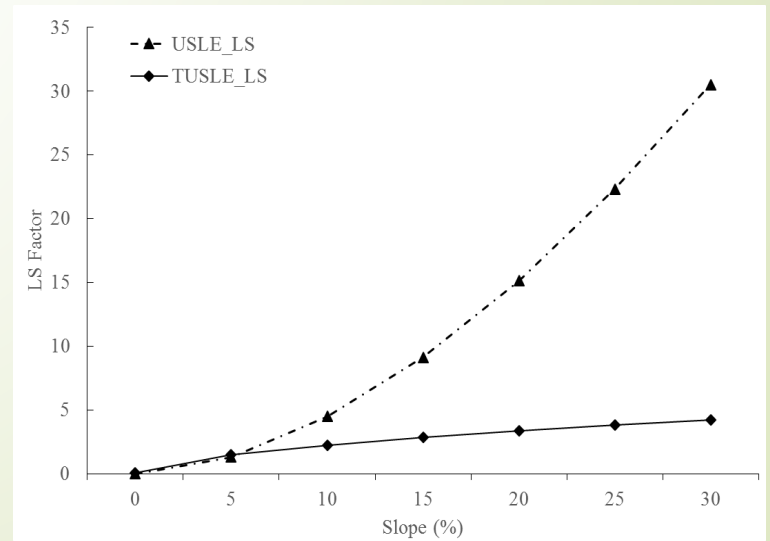
- Slope Length = 10 m



- Slope Length = 30 m



- Slope Length = 50 m



Flow calibration and validation



Rating curve



Sediment initial simulation



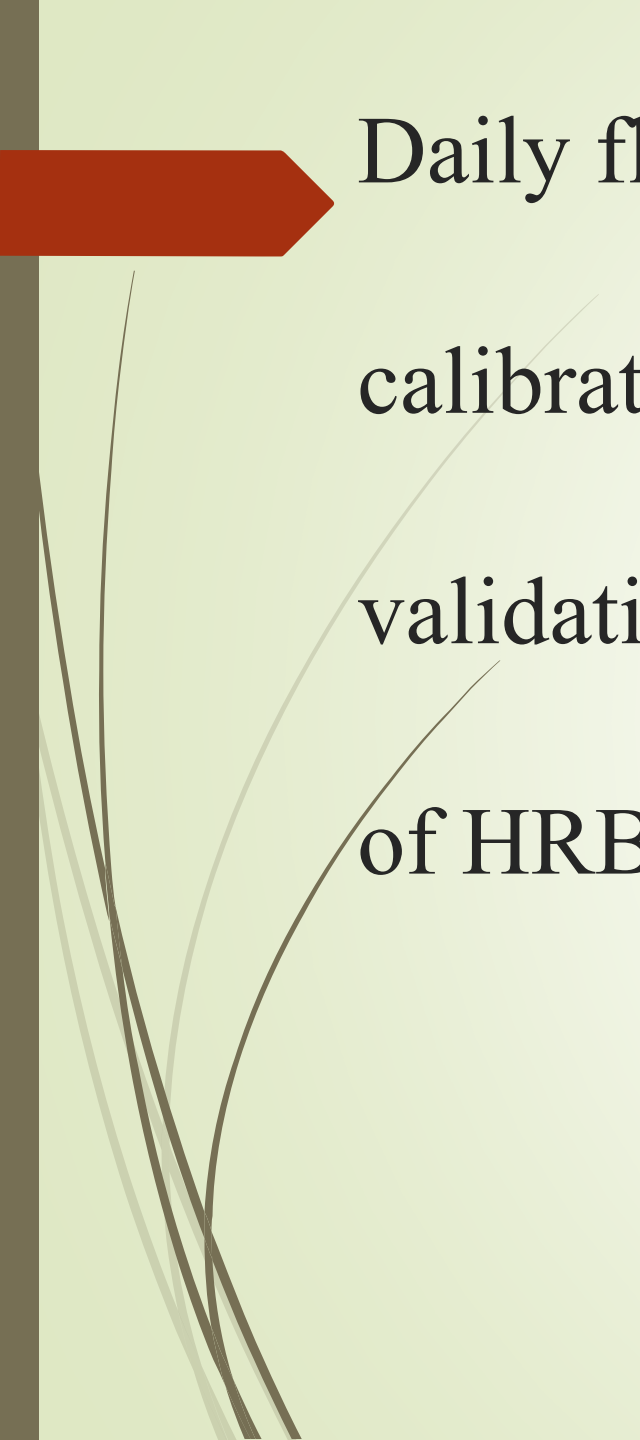
Sediment calibration



Sediment validation

Result flow chart

**Comparison
of SWAT2012
and SWAT-
Twn**



Daily flow calibration and validation result of HRB

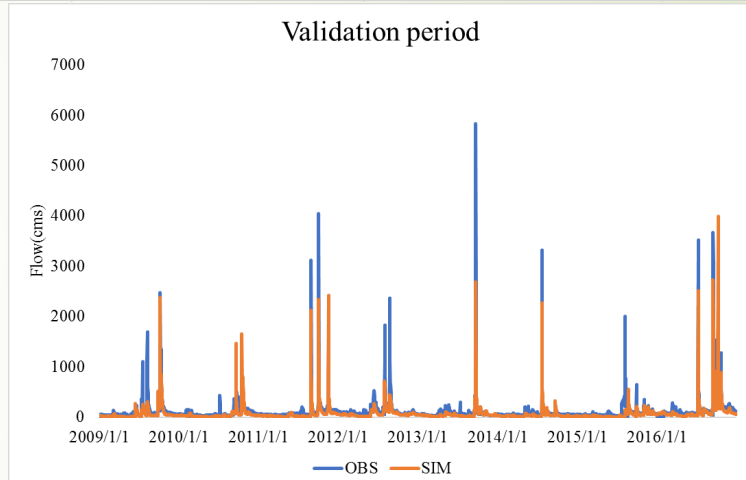
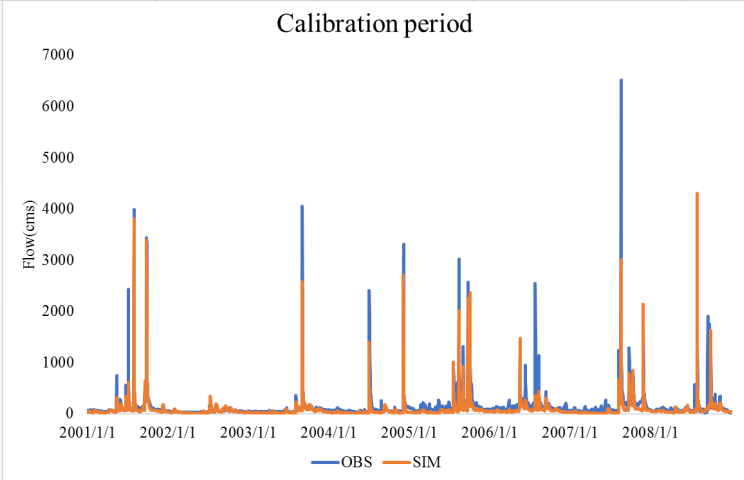
Parameter Name	Subbasin	File name	Method	Min	Max
CN2	HLB	.mgt	Relative	-0.3	0.5
CN2	JYB	.mgt	Relative	-0.2	0.5
SOL_AWC	HLB	.sol	Relative	-0.6	0.3
ESCO	All	.hru	Replace	0	0.6
SURLAG	HLB	.hru	Replace	5	24
SURLAG	JYB	.hru	Replace	5	24
ALPHA_BF	HLB	.gw	Replace	0.5	1
GW_REVAP	HLB	.gw	Replace	0.05	0.16
GW_REVAP	JYB	.gw	Replace	0.02	0.1
GWQMN	HLB	.gw	Replace	0	3700
GWQMN	JYB	.gw	Replace	0	3500
RCHRG_DP	HLB	.gw	Replace	0.2	0.7
RCHRG_DP	JYB	.gw	Replace	0	0.5
OV_N	HLB	.hru	Replace	0.01	20
SLSUBBSN	HLB	.hru	Relative	-0.3	0.5
CANMX	FRST	.hru	Replace	30	85
HRU_SLP	JYB	.hru	Relative	-0.5	0.1
CH_N2	HLB	.rte	Replace	0.1	0.3
CH_K2	HLB	.rte	Replace	300	500
CH_K1	JYB	.sub	Replace	80	220

Flow calibration and validation result

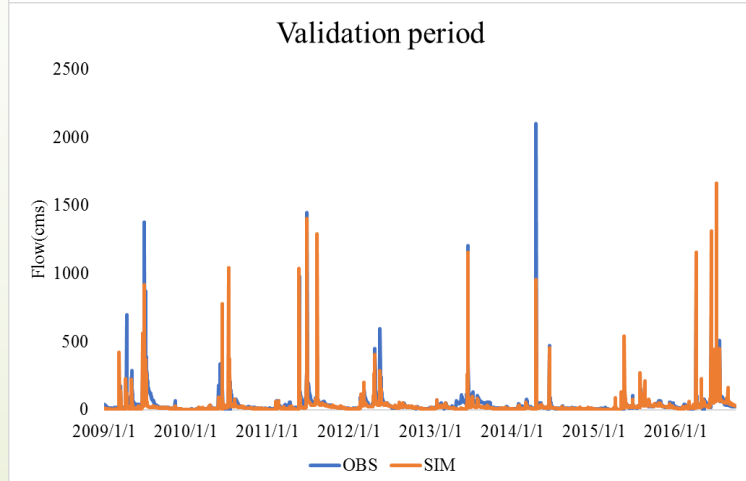
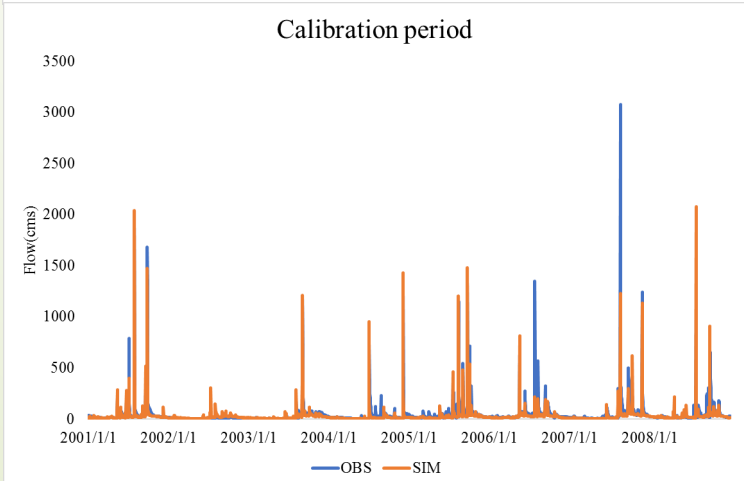
	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
calibration	2001~2008	0.71	0.66	38.8	0.58	81.12	132.59	Good
validation	2009~2016	0.69	0.64	38.4	0.6	72.24	117.23	Satisfactory

	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
calibration	2001~2008	0.61	0.6	30.1	0.63	29.54	42.29	Satisfactory
validation	2009~2016	0.63	0.6	27.6	0.63	28.22	39.01	Satisfactory

Hua-lien-Bridge

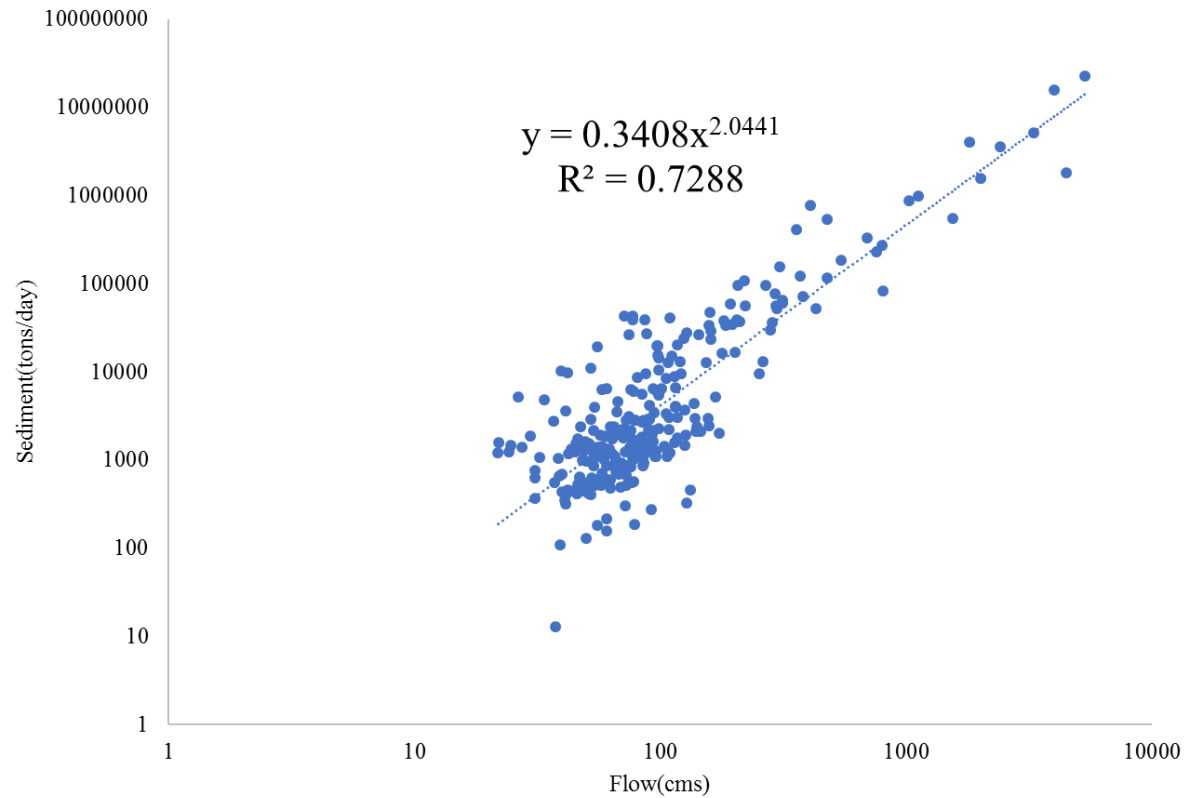


Jian-Ying-Bridge

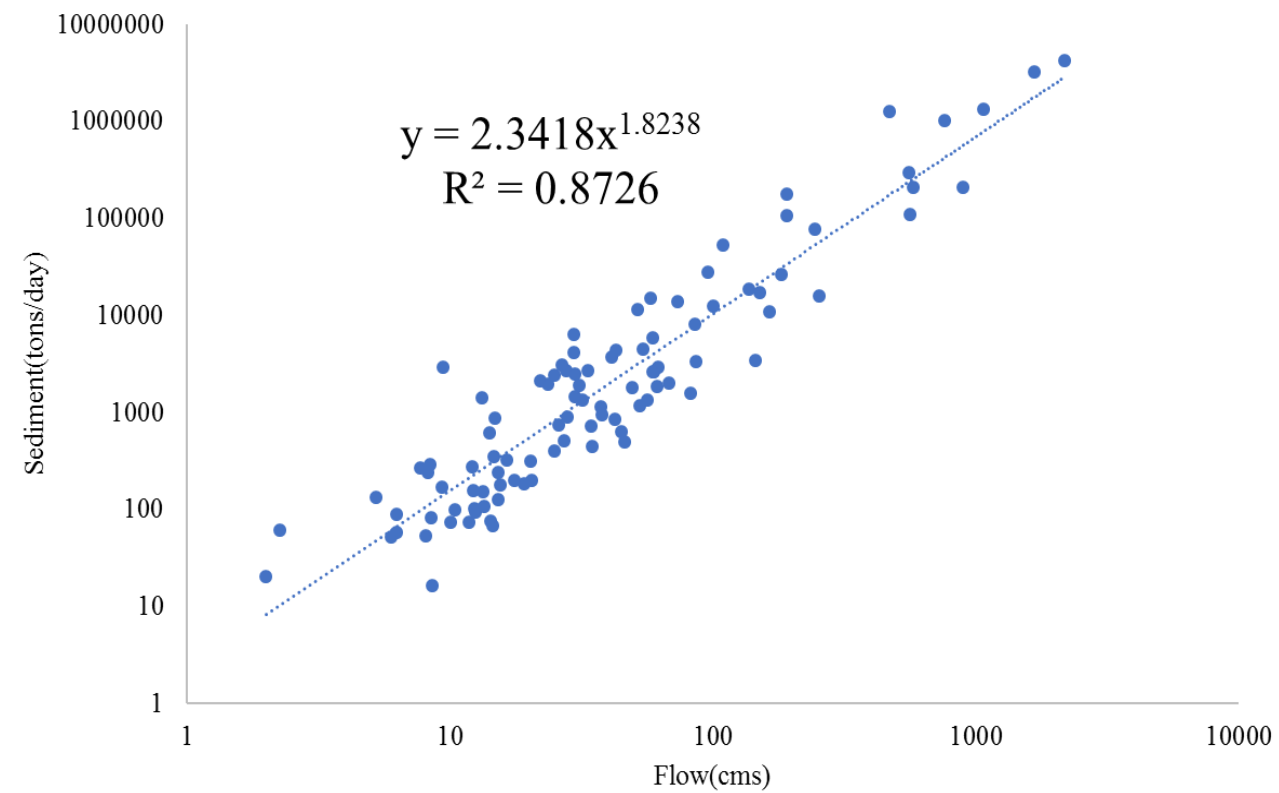


Rating curve of Hualian River

Hua-lien-Bridge(HLB)



Jian-Ying-Bridge(JYB)



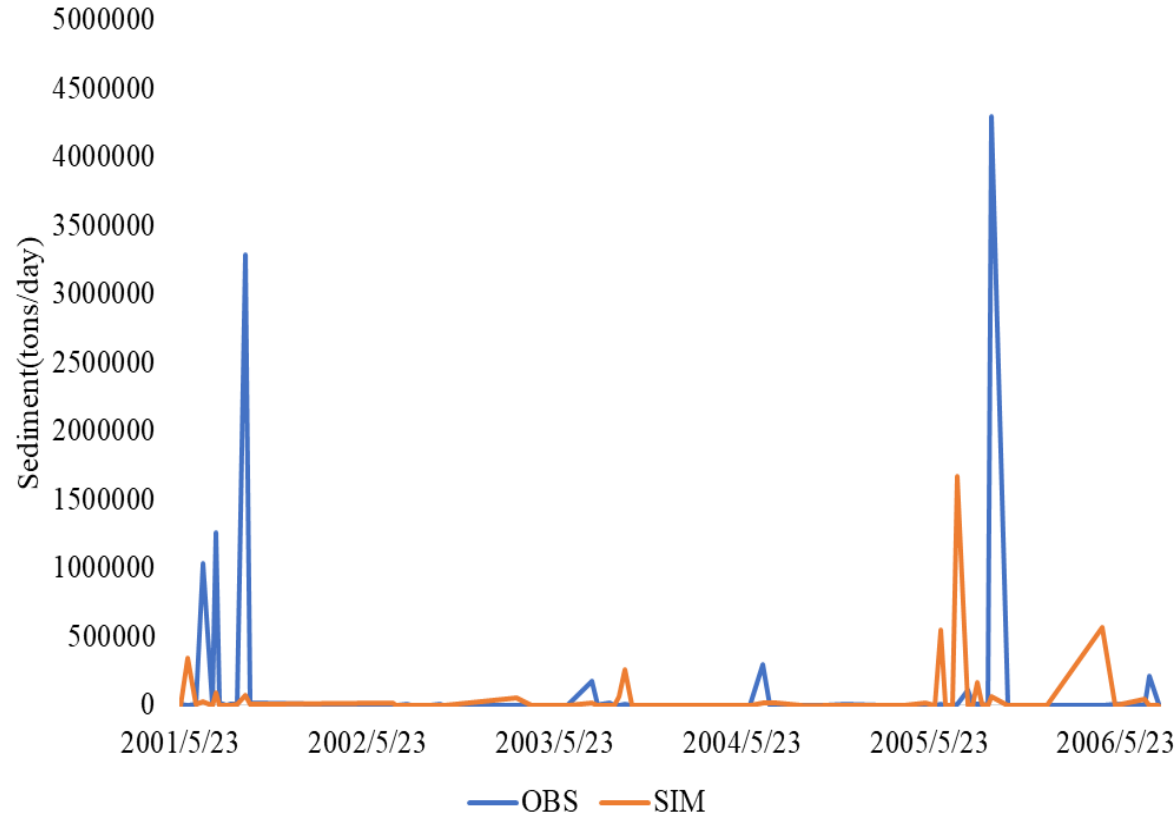
Sediment transport calibration and validation result of HRB

Parameter Name	Subbasin	File name	Method	Min	Max
SPCON	JYB	.bsn	Replace	0.001	0.007
CH_COV2	JYB	.rte	Replace	0.55	1
CH_ERODMO	JYB	.rte	Replace	0.3	0.75
SLSUBBSN	HLB	.hru	Relative	-0.15	0.3
CH_BNK_D50	HLB	.rte	Replace	3300	10000
CH_BED_D50	HLB	.rte	Replace	1	5500

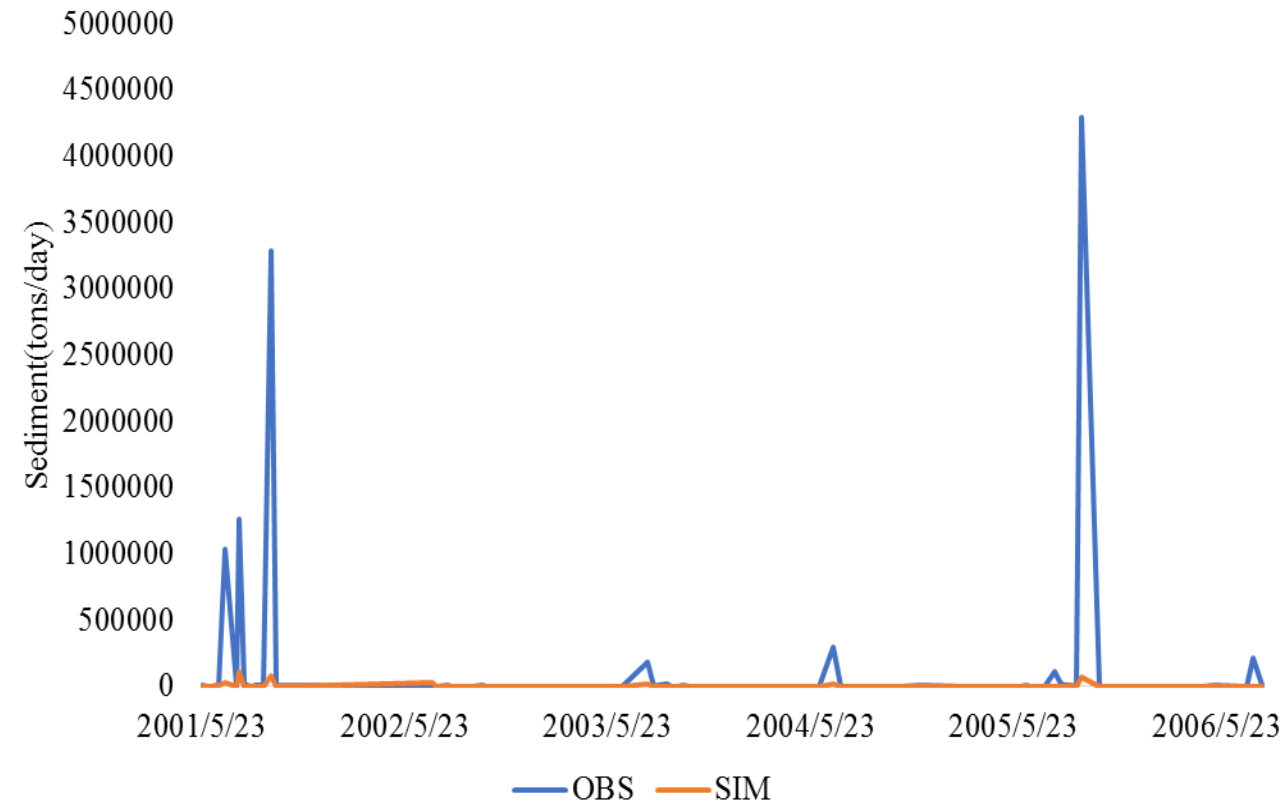
Sediment initial simulation of JYB

	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
SWAT2012	2001~2008	0	-0.14	62.1	1.07	65229	171883	Unsatisfactory
SWAT-Twn	2001~2008	0.62	-0.02	96.5	1.01	5934	171883	Unsatisfactory

SWAT2012-Initial simulation

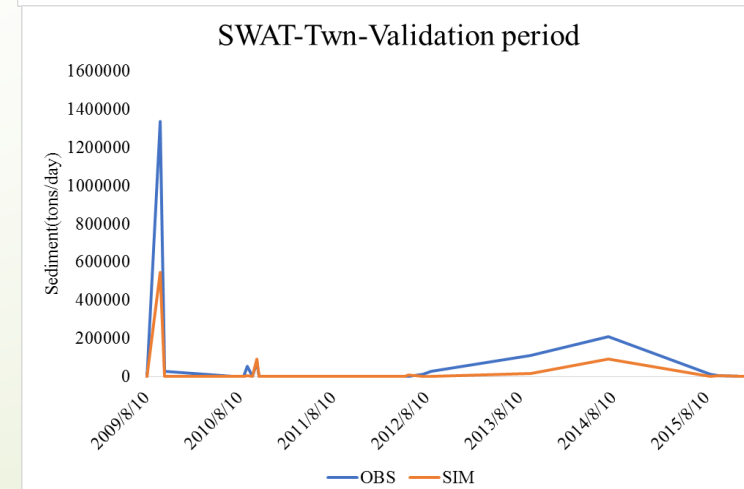
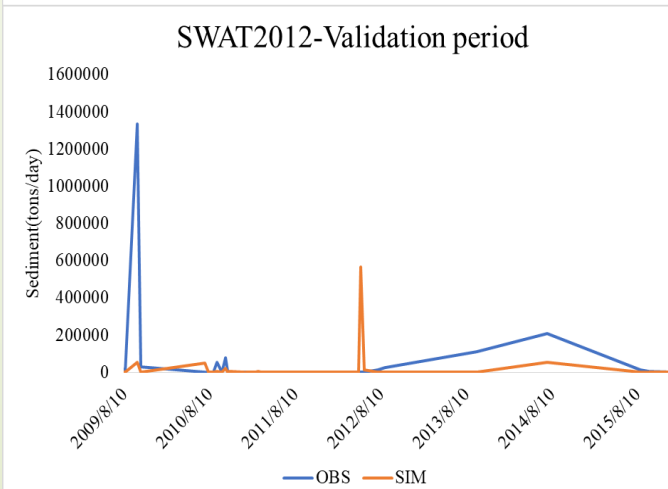
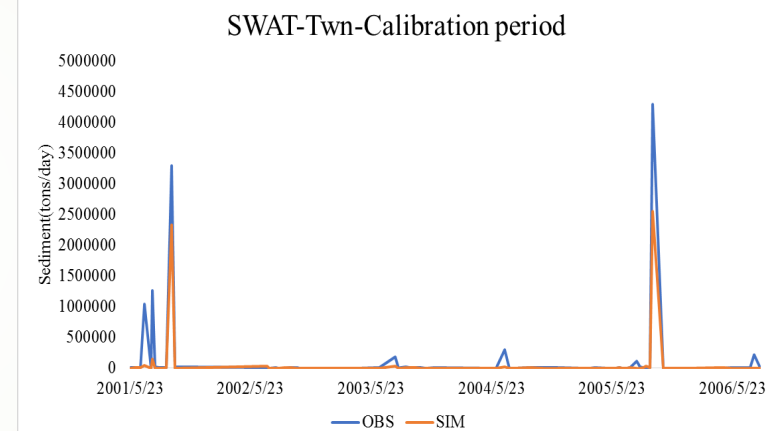
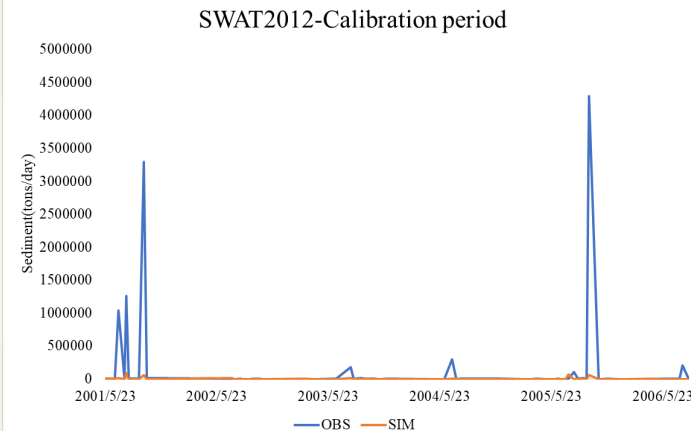


SWAT-Twn-Initial simulation



Sediment calibration and validation of JYB

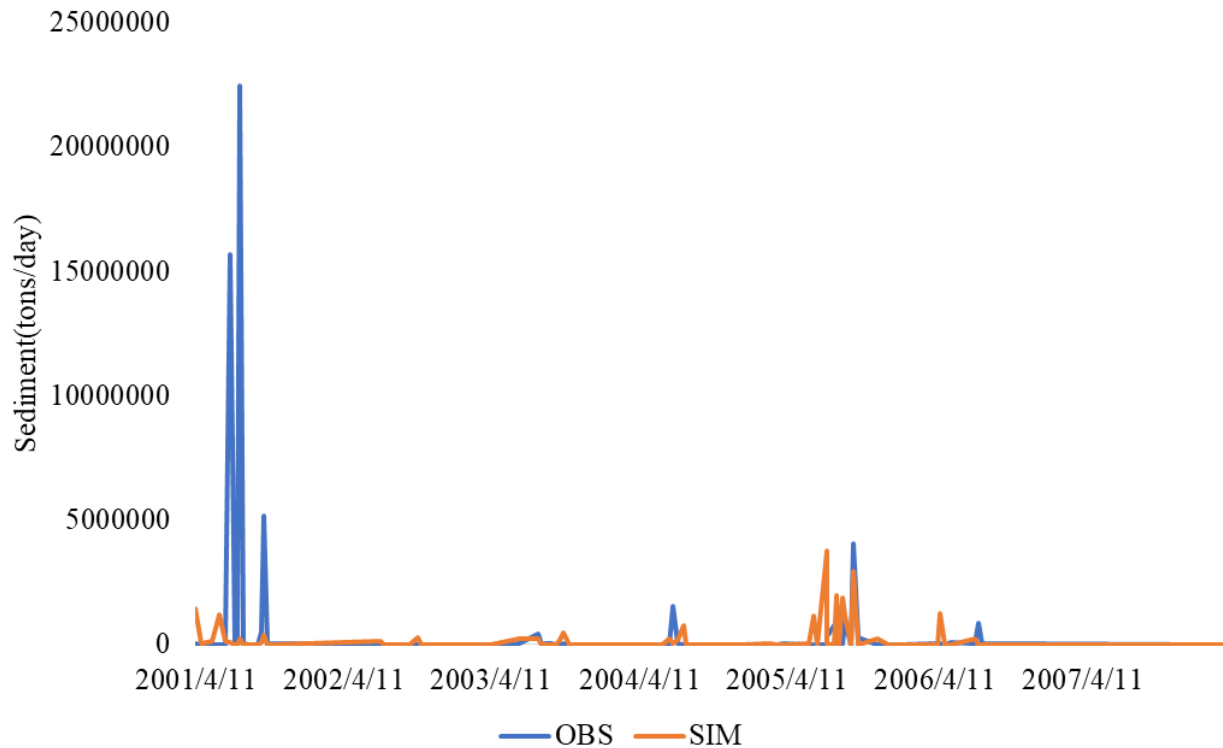
	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
SWAT2012	2001~2008	0.51	-0.02	96.7	1.01	5653	171883	Unsatisfactory
SWAT-Twn	2001~2008	0.92	0.79	51.6	0.46	83182	171883	Satisfactory
	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
SWAT2012	2009~2016	0	-0.15	59.4	1.07	21465	52912	Unsatisfactory
SWAT-Twn	2009~2016	0.98	0.63	58.4	0.61	22034	52912	Satisfactory



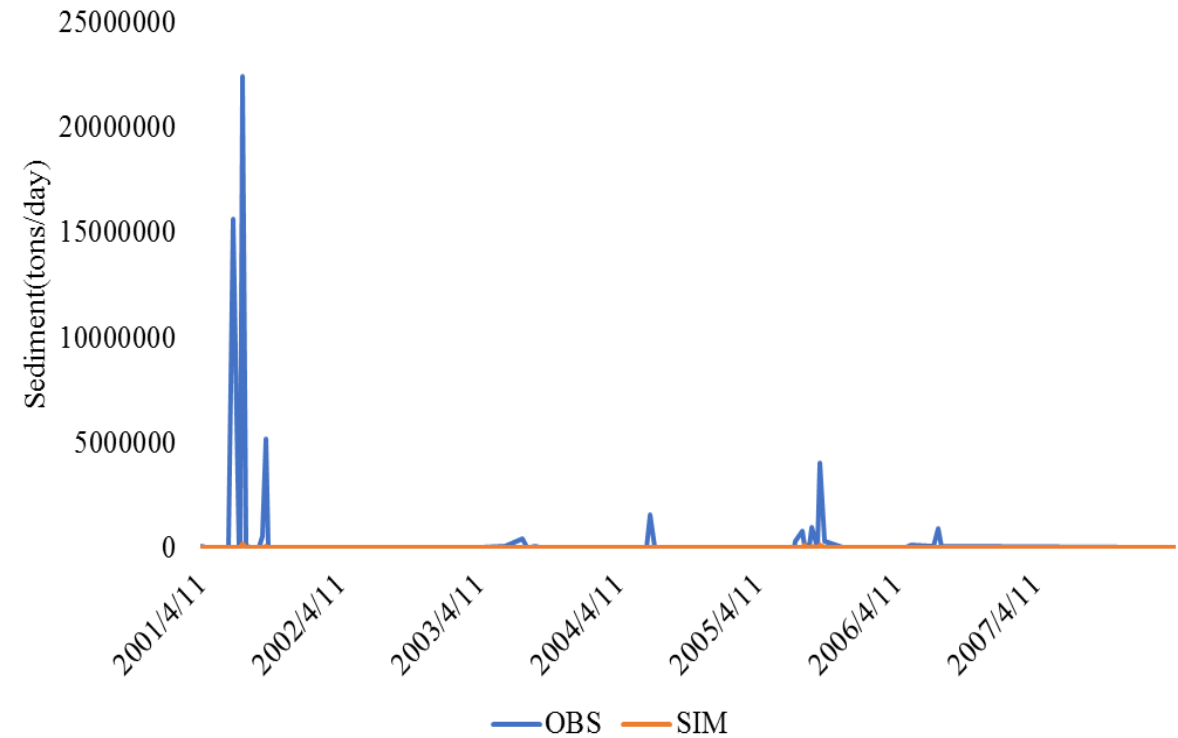
Sediment initial simulation of HLB

Model	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
SWAT2012	2001~2008	0	-0.05	60.9	1.02	277891	711294	Unsatisfactory
SWAT-Twn	2001~2008	0.52	-0.04	98.8	1.02	8734.14	711294	Unsatisfactory

SWAT2012-Initial simulation

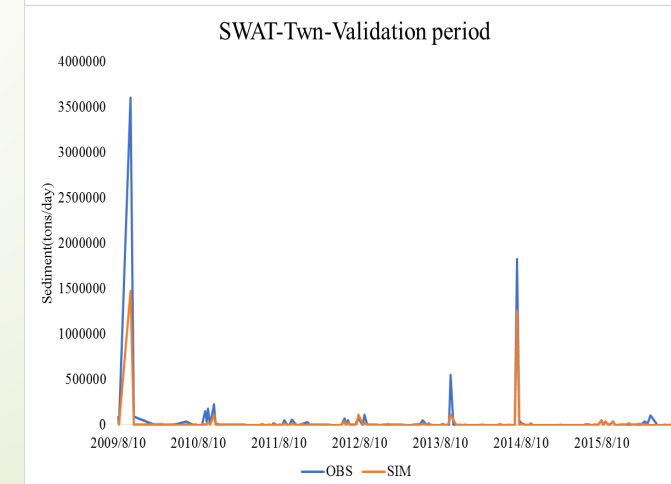
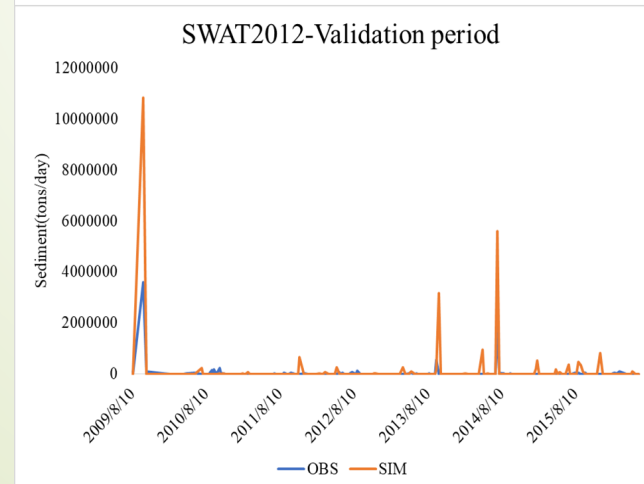
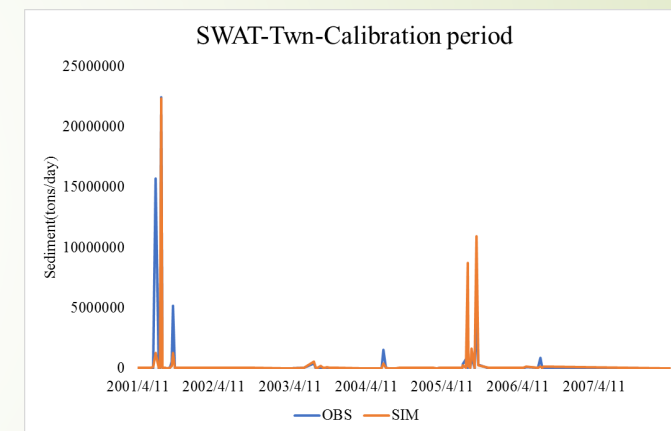
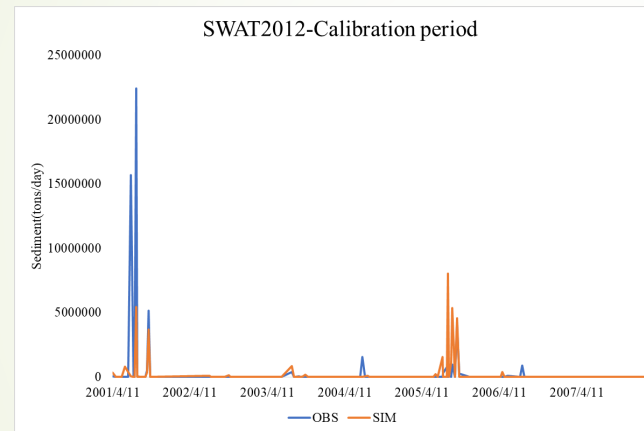


SWAT-Twn-Initial simulation



Sediment calibration and validation of HLB

	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
SWAT2012	2001~2008	0.18	0.17	37.3	0.91	446291	711294	Unsatisfactory
SWAT-Twn	2001~2008	0.57	0.54	6.9	0.68	662050	711294	Satisfactory
	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
SWAT2012	2009~2016	0.89	-3.86	-217.5	2.2	135682	42739	Unsatisfactory
SWAT-Twn	2009~2016	0.93	0.69	49	0.56	21817	42739	Good



Daily flow calibration and validation result of ZRB

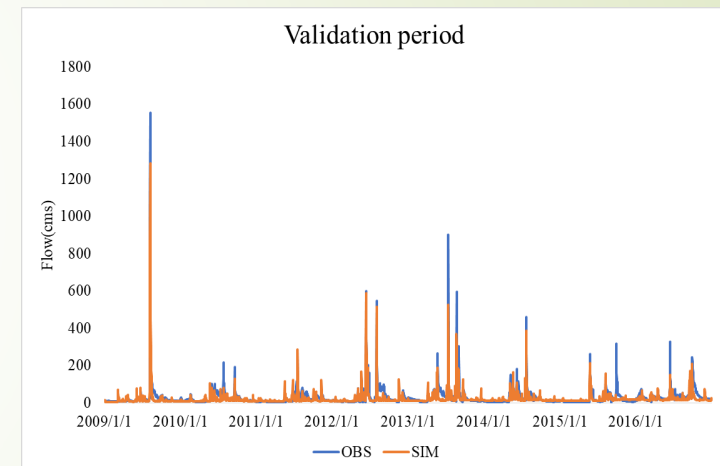
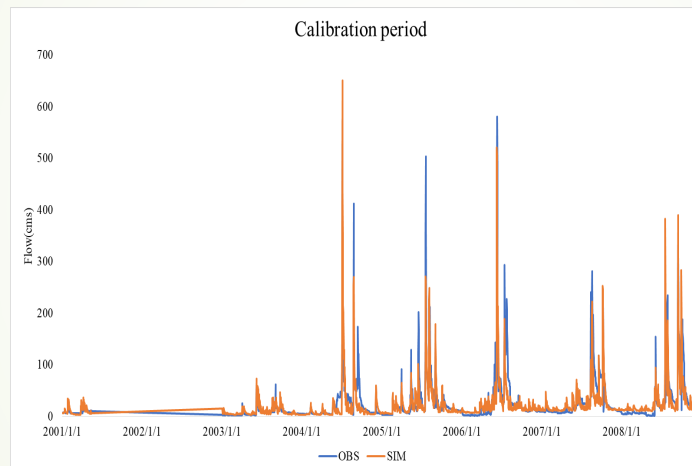
Parameter Name	Subbasin	File name	Method	Min	Max
CN2	NMP	.mgt	Relative	0.15	0.8
CN2	CCB	.mgt	Relative	-0.6	0.2
SURLAG	NMP	.hru	Replace	0.05	10
SURLAG	CCB	.hru	Replace	15	24
ALPHA_BF	CCB	.gw	Replace	0.5	1
GW_DELAY	NMP	.gw	Replace	280	50
GWQMN	NMP	.gw	Replace	1000	3000
GWQMN	CCB	.gw	Replace	2800	5000
RCHRG_DP	NMP	.gw	Replace	0.3	0.65
CANMX	FRST	.hru	Replace	50	100
CH_K2	CCB	.rte	Replace	270	500
CH_K1	NMP	.sub	Replace	85	200

Flow calibration and validation result

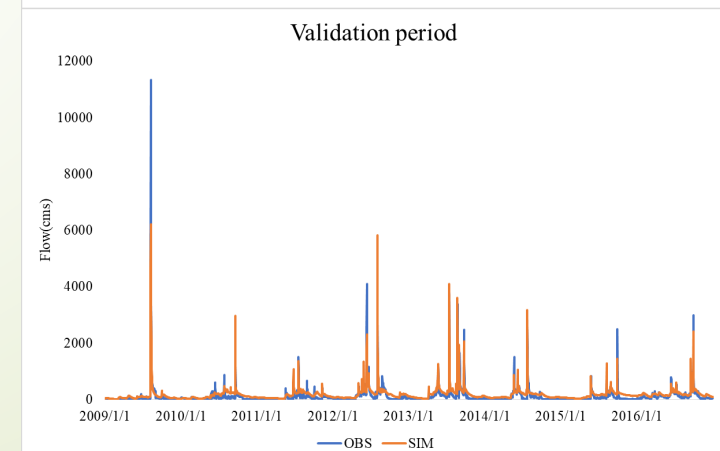
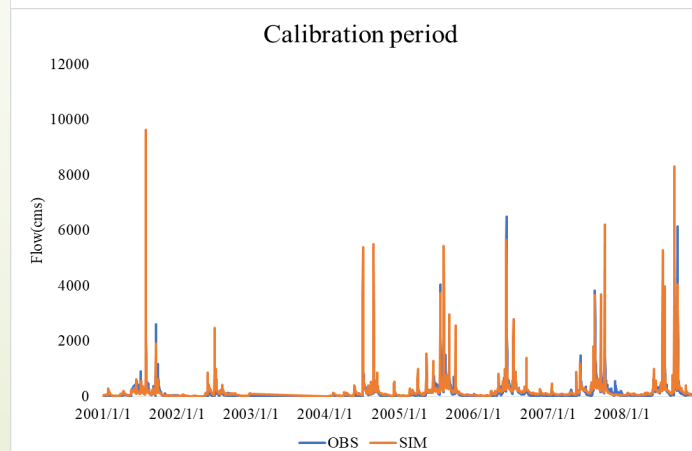
	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
calibration	2001~2008	0.71	0.71	5	0.54	23.73	24.97	Good
validation	2009~2016	0.76	0.75	20.6	0.5	22.33	28.12	Good

	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
calibration	2001~2008	0.71	0.63	-17.9	0.61	193.92	164.48	Satisfactory
validation	2009~2016	0.7	0.66	-58.2	0.58	174.79	110.48	Satisfactory

Nei-Mao-Pu

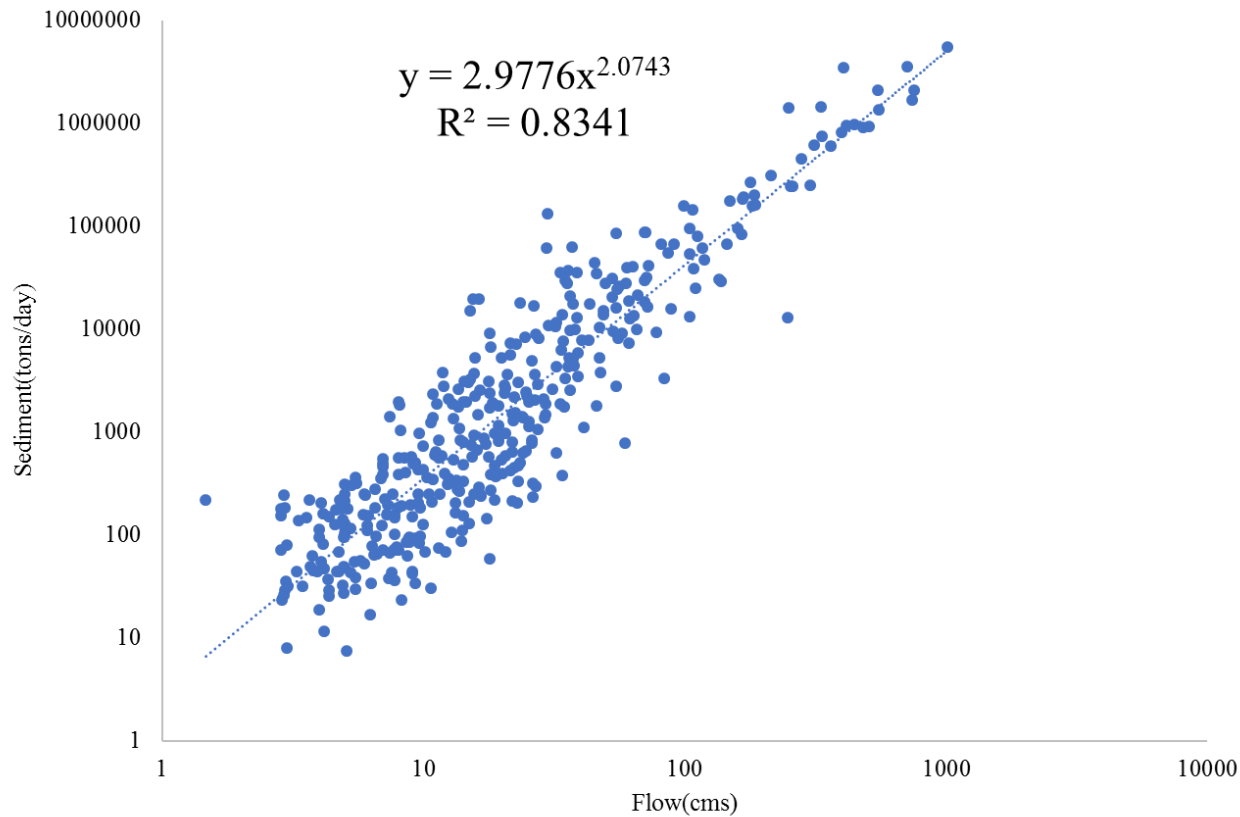


Chi-Chou-Bridge

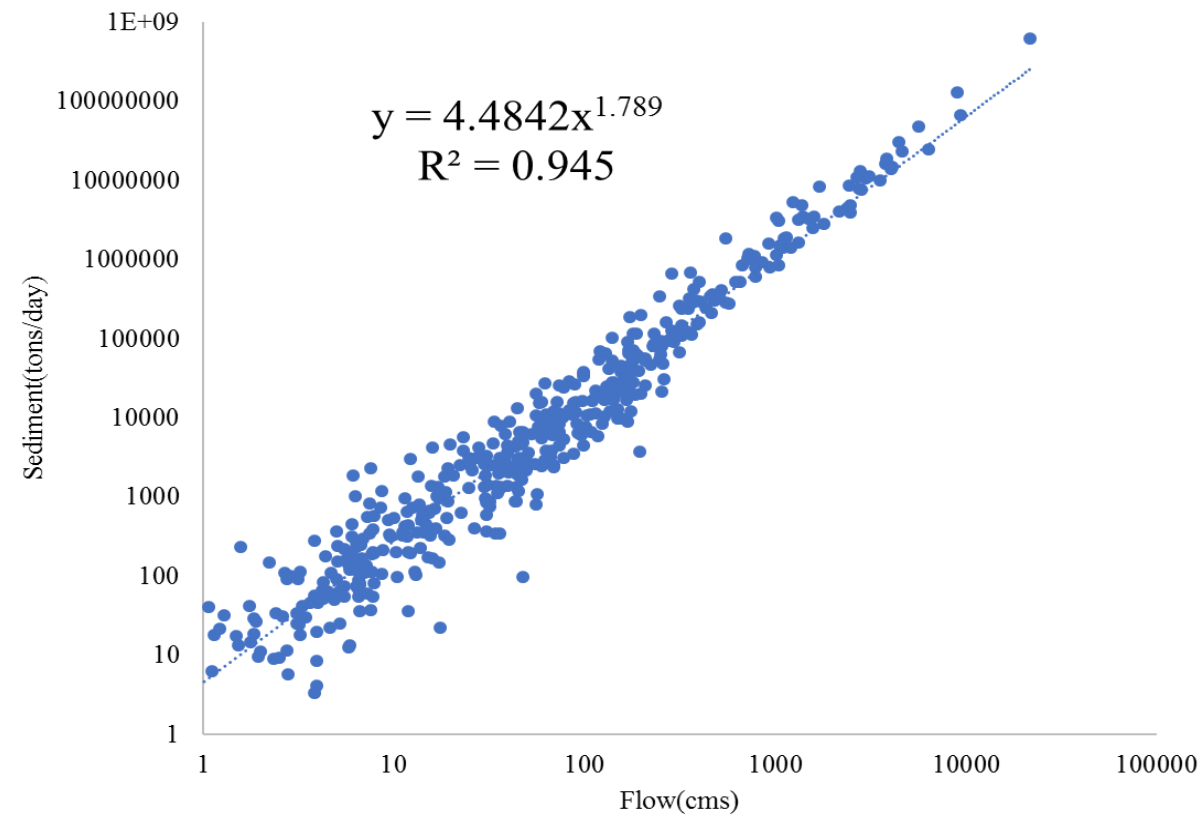


Rating curve of Zhuoshui River

Nei-Mao-Pu(NMP)



Chi-Chou-Bridge(CCB)



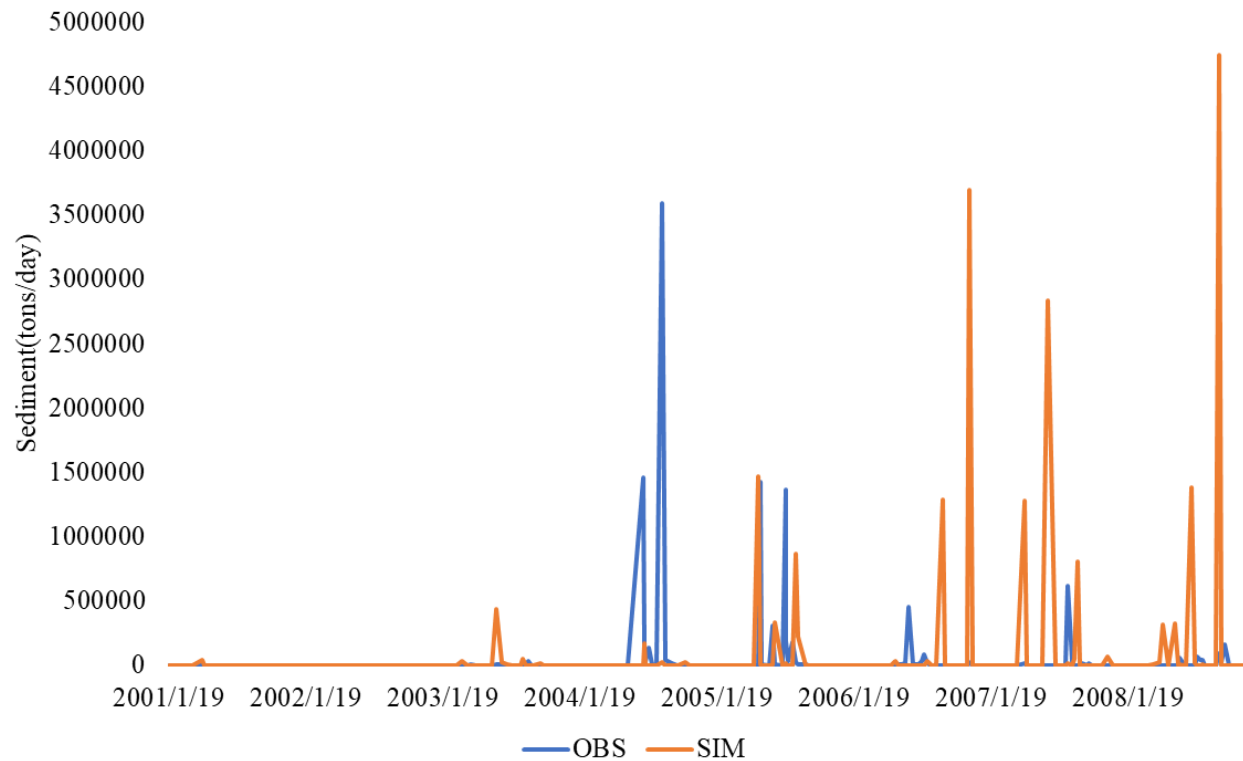
Sediment transport calibration and validation result of ZRB

Parameter Name	Subbasin	File name	Method	Min	Max
PRF_BSN	All	.bsn	Replace	0.5	1.6
ADJ_PKR	All	.bsn	Replace	1	1.6
SPCON	All	.bsn	Replace	0.001	0.006
SPEXP	All	.bsn	Relative	1.1	1.4
USLE_K	All	.sol	Replace	0.35	0.65
SLSOIL	NMP	.hru	Relative	0	0.7
SLSOIL	CCB	.hru	Relative	-0.8	0.1
CH_BNK_D50	NMP	.rte	Replace	2000	6500

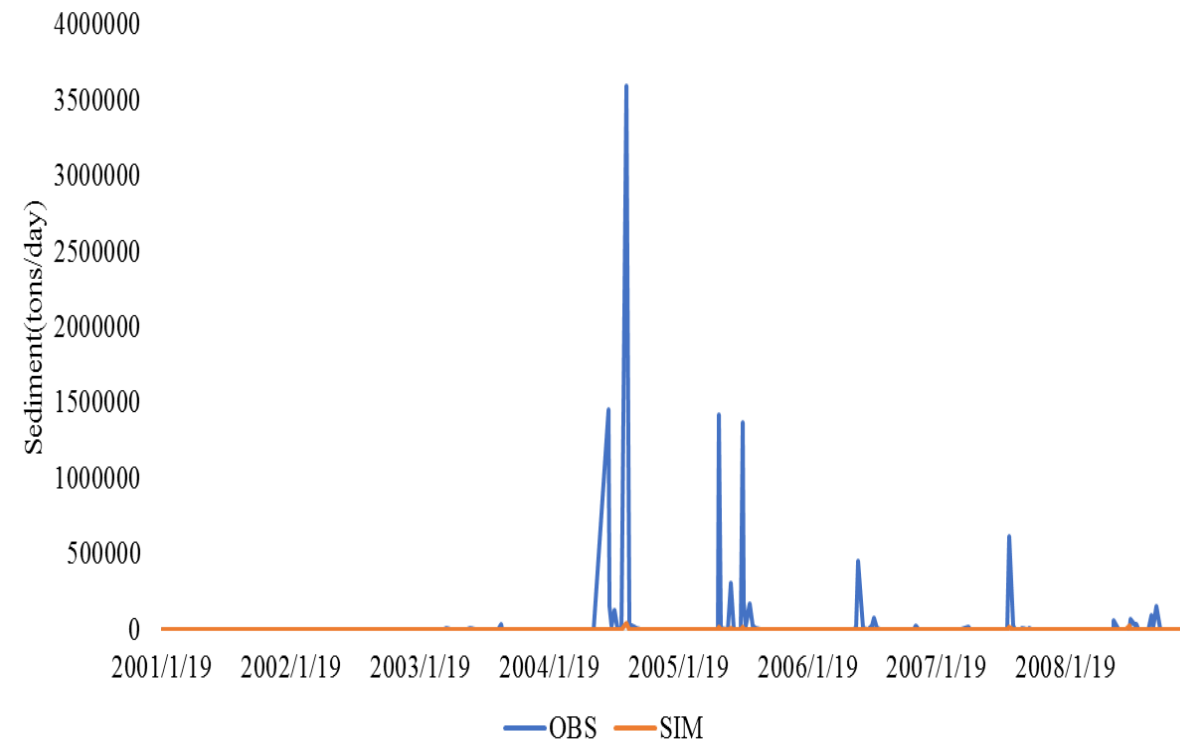
Sediment initial simulation of NMP

	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
SWAT2012	2001~2008	0	-2.75	-87.7	1.94	111791	59544	Unsatisfactory
SWAT-Twn	2001~2008	0.66	-0.01	97.7	1	1367	59544	Unsatisfactory

SWAT2012-Initial simulation

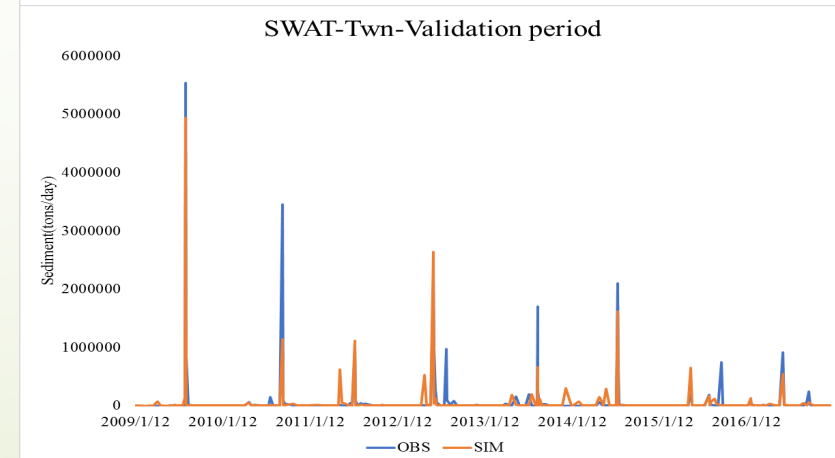
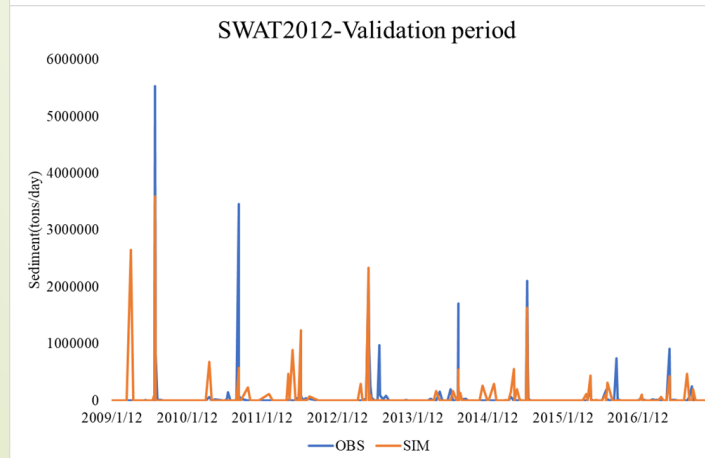
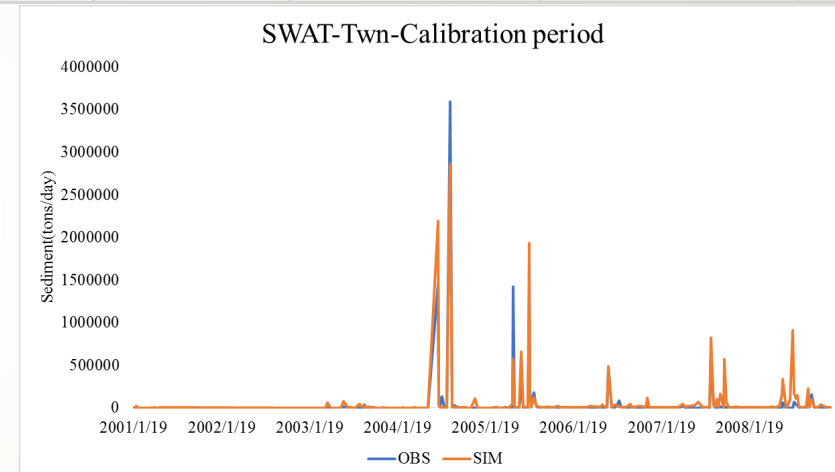
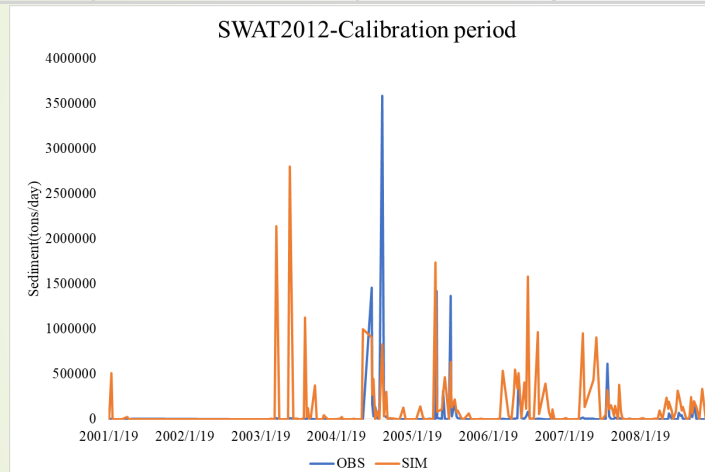


SWAT-Twn-Initial simulation



Sediment calibration and validation of NMP

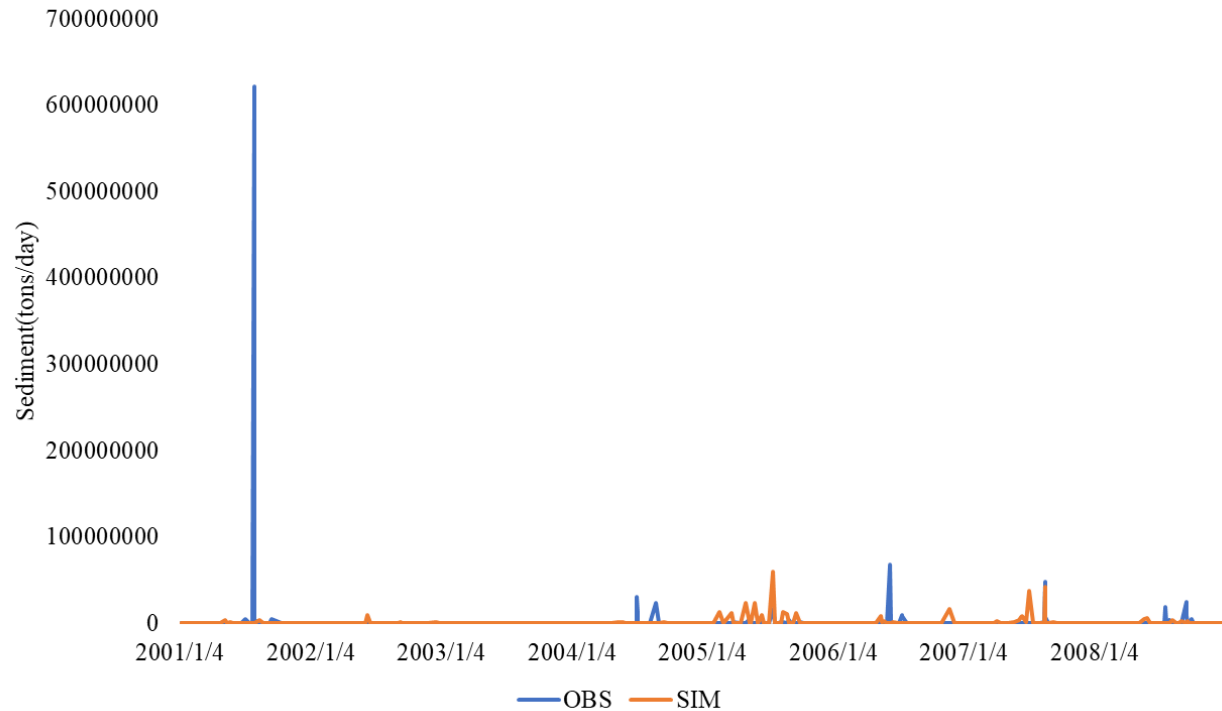
	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
SWAT2012	2001~2008	0.05	-0.85	-160	1.36	154790	59544	Unsatisfactory
SWAT-Twn	2001~2008	0.82	0.81	-34.7	0.44	80195	59544	Good
	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
SWAT2012	2009~2016	0.52	0.52	17.1	0.69	91285	110155	Satisfactory
SWAT-Twn	2009~2016	0.8	0.79	25.2	0.46	82350	110155	Good



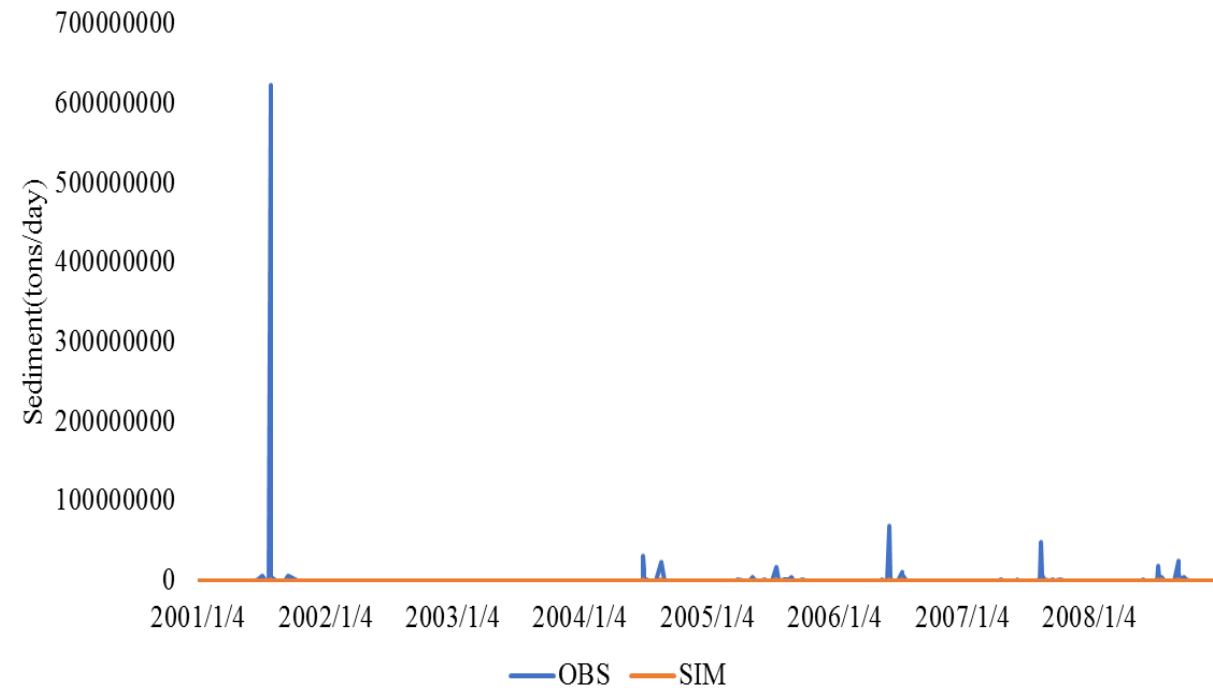
Sediment initial simulation of CCB

	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
SWAT2012	2001~2008	0	-0.02	61.4	1.01	1692390	4385509	Unsatisfactory
SWAT-Twn	2001~2008	0.5	-0.01	99.5	1	22966	4385509	Unsatisfactory

SWAT2012-Initial simulation

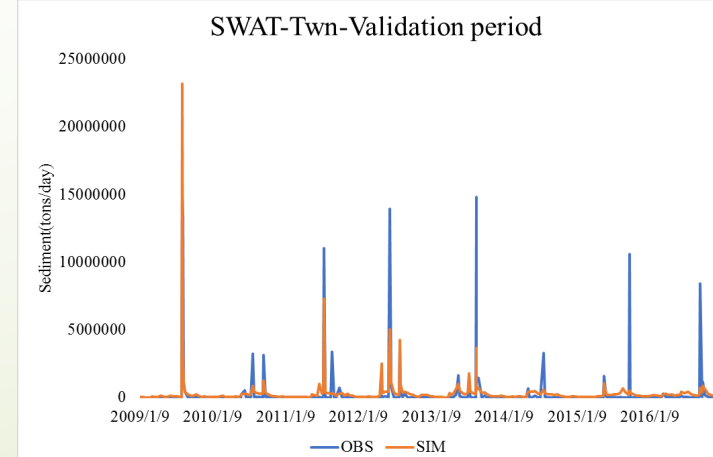
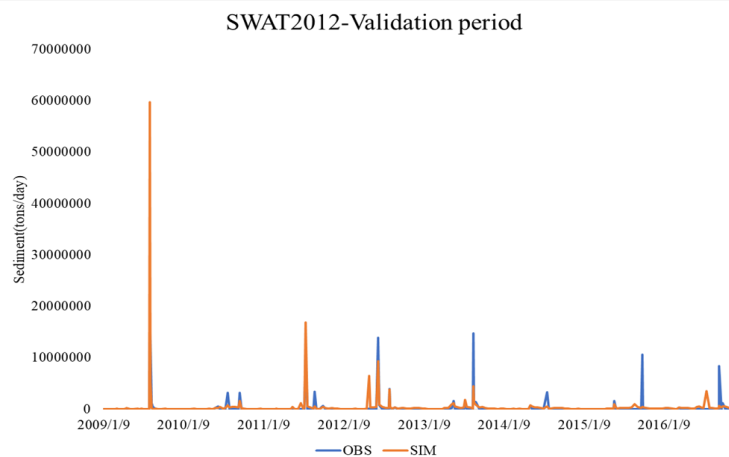
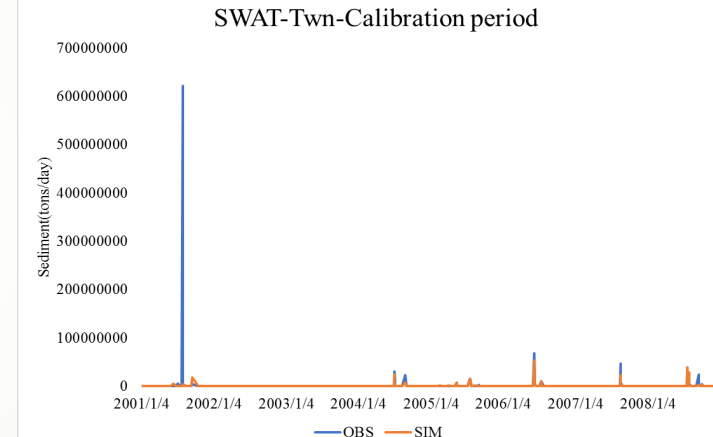
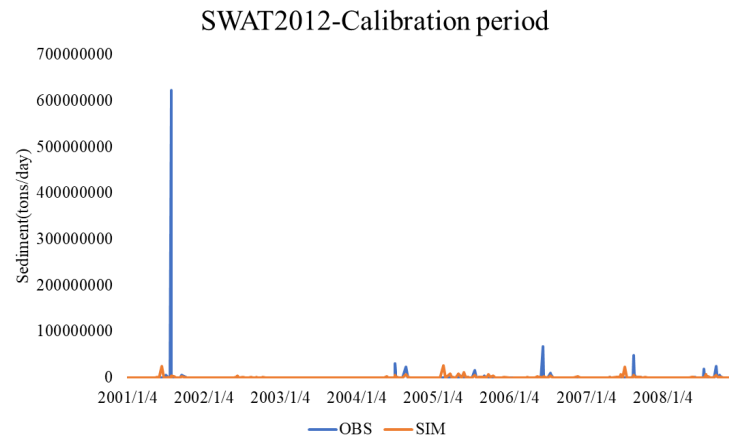


SWAT-Twn-Initial simulation



Sediment calibration and validation of CCB

	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
SWAT2012	2001~2008	0.07	0.03	71.7	0.98	1239310	4385509	Unsatisfactory
SWAT-Twn	2001~2008	0.61	0.26	58.6	0.86	1813655	4385509	Unsatisfactory
	Period	R ²	NSE	PBIAS	RSR	Mean_sim	Mean_obs	Result
SWAT2012	2009~2016	0.38	-1.21	-31.5	1.49	658974	501082	Unsatisfactory
SWAT-Twn	2009~2016	0.48	0.48	16.5	0.72	418216	501082	Unsatisfactory



Conclusion

- Based on the comparison results on sediment simulation, the SWAT-Twn performed better than SWAT2012, indicating that adjusting LS calculation and integrating landslide simulation could effectively improve the sediment transportation in Taiwan.
- For both basins, sediment transport simulation were much improved when the Yang sand and gravel transport model was applied on the downstream subwatersheds, indicating that a single sediment transport model may not be suitable for the entire watershed.
- It was found that sediment export from ZRB in western Taiwan were more sensitive to the upland process (parameters: PRF_BSN, ADJ_PKR, SPCON and SPEXP), while sediment export from HRB in eastern Taiwan were more sensitive to the channel characteristics (parameters: CH_COV2, CH_BNK_D50 and CH_BED_D50). Thus, further consideration of selecting parameters for calibration is needed for watersheds of different geomorphological characteristics.



Thank you for listening