Evaluation of SWAT Hydrological Model for Streamflow Simulation In Yasu River, Japan

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Outline

- Introduction
- Objectives
- Study area

  Yasu River Basin, Japan
- Methodology (SWAT CUP)

  Sensitivity Analysis, Calibration, Validation, Uncertainty Analysis
- Results
- Conclusion
- Future Plan

Introduction

- Water is fundamental resources for all lives on earth including human beings.
- High threats such as increasing population, pollution, and climate change lie in its future availability.
- Establishment of sustainable water use is urgent need.
- For suitable water management, grasping local hydrological environment and local climate is inevitable.
- Hydrological modeling is one of the most popular method.
- SWAT (Soil Water Assessment Tool) is employed to model Japanese basin.

Objectives

Main Objective

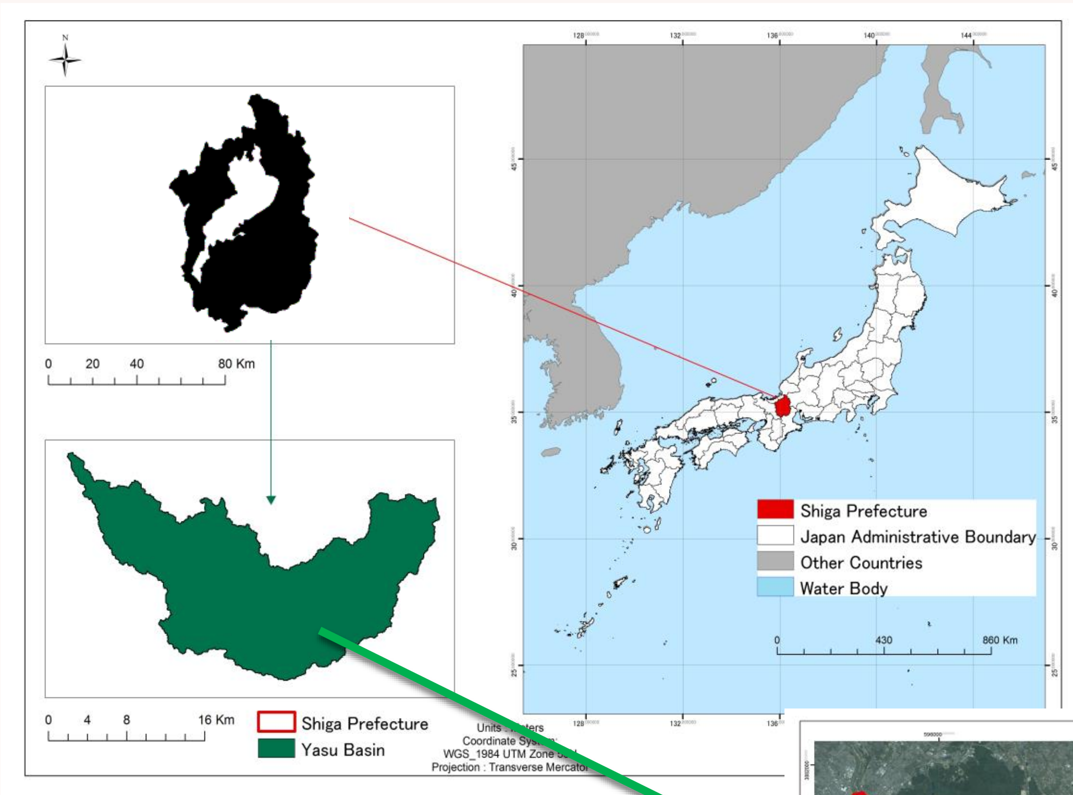
- To simulate streamflow in Yasu River Basin, Japan

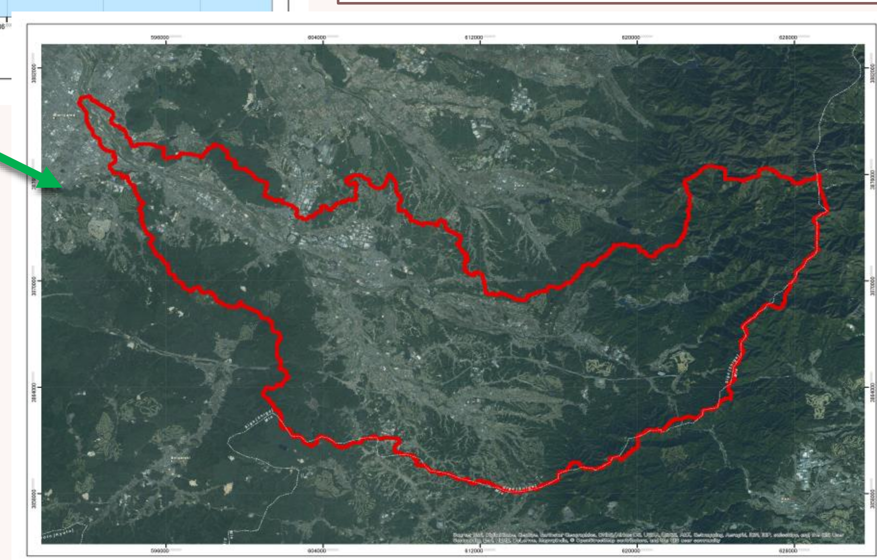
> Relatively small and steep basin with dams, irrigation ponds, agricultural water channel network and so on

Specific objectives

- To check availability of SWAT to Japanese basin through **sensitivity analysis**, **calibration**, **validation**, and **uncertainty analysis**.

Study area: Yasu River basin





Elevation

- 97masl to 1235masl

Land use

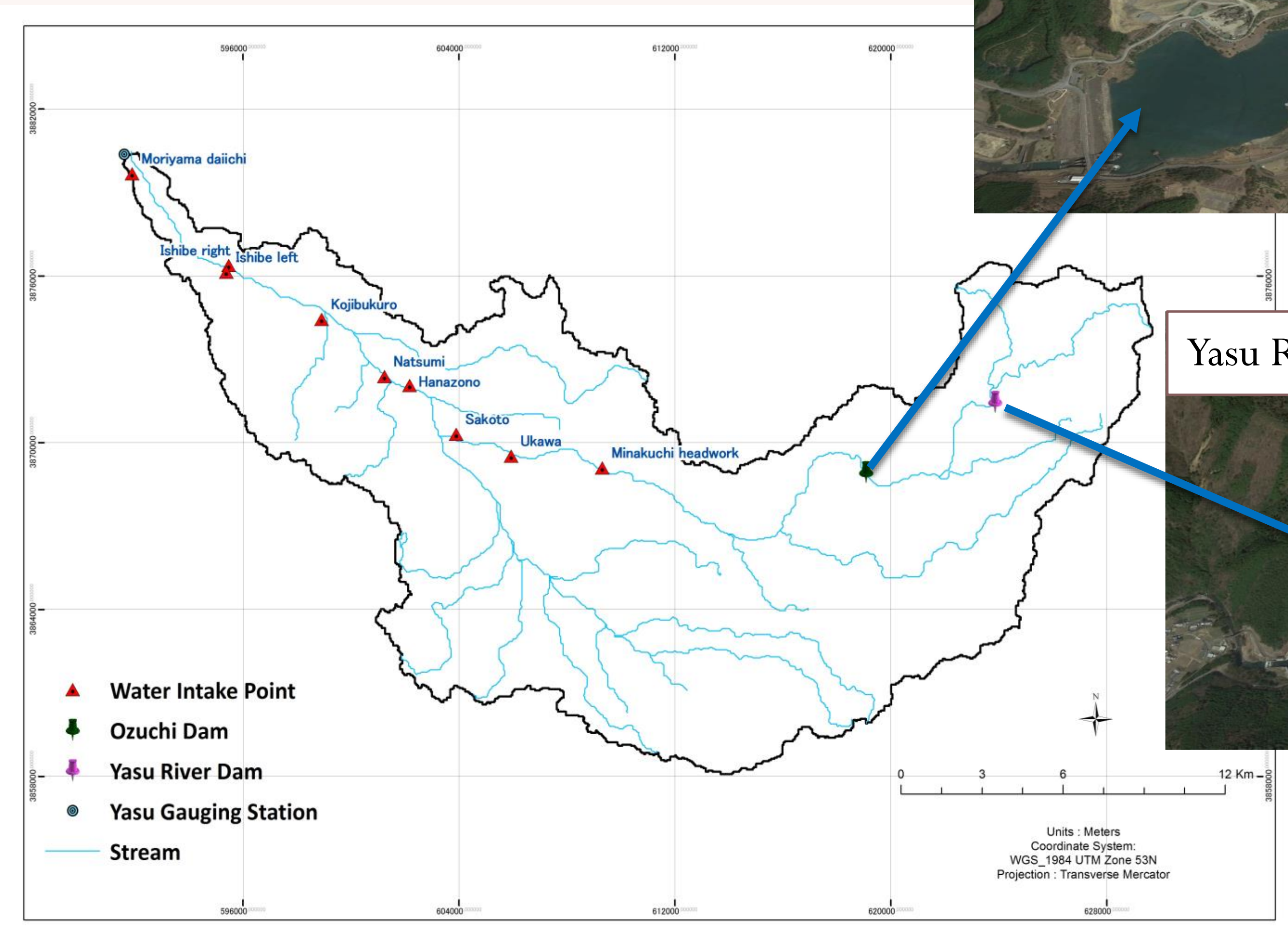
- Forest, Paddy field, Settlement

Soil

- Brown forest soil

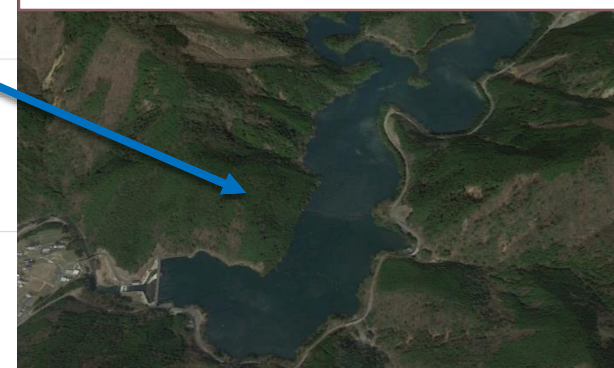
Rain:	1,587 mm
Area:	377 km²
Length:	65 Km

Study area: Yasu River basin



Ozuchi Dam (7.3 million m^3)

Yasu River Dam (8.5 million m^3)



SWAT model

Uses water balance equation (Arnold et al 1998)

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

SW_t = final soil water content (mm)
SW_0 =soil water content on day i (mm)
t = time in days
R_{day} = of precipitation on day i (mm)
Q_{surf} =amount of surface runoff on day i (mm)
E_a =amount of evaporation on day i (mm)
W_{seep} =amount of water entering the vadose zone from soil profile on day i (mm)
Q_{gw} = amount of return flow on day i (mm)

SWAT CUP (Calibration and Uncertainty Programs)

- Application that conducts calibration, validation, and sensitivity and uncertainty analyses for SWAT model.
- Optimization programs

  SUFI-2 (Sequential Uncertainty Fitting)

  GLUE (Generalized Likelihood Uncertainty Estimation)

Sensitivity analysis

- Sensitivity is given as the average change of objective function as a result of change in each parameter.

$$g = \alpha + \sum_{i=1}^{m} \beta_i b_i$$

$\alpha = \frac{\sigma_s}{\sigma_m}$

$\beta = \frac{\mu_s}{\mu_m}$

b_i = parameter,

σ_s and σ_m = standard deviation of simulated and measured data

μ_s and μ_m = are means of simulated and measured data.

Model Efficiency

- By R^2 (coefficient of determination) and NS (Nash-Sutcliffe), the model efficiency is evaluated.

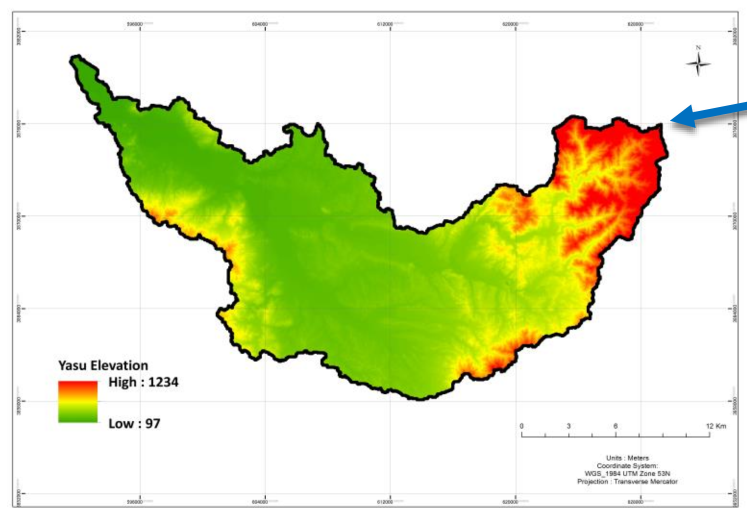
$$R^2 = \frac{\left[\sum_{i=1}^{n}\left(Q_{obs,i} - \bar{Q}_{obs}\right)\left(Q_{sim,i} - \bar{Q}_{sim}\right)\right]^2}{\sum_{i=1}^{n}\left(Q_{obs,i} - \bar{Q}_{obs}\right)^2 \sum_{i=1}^{n}\left(Q_{sim,i} - \bar{Q}_{sim}\right)^2}$$

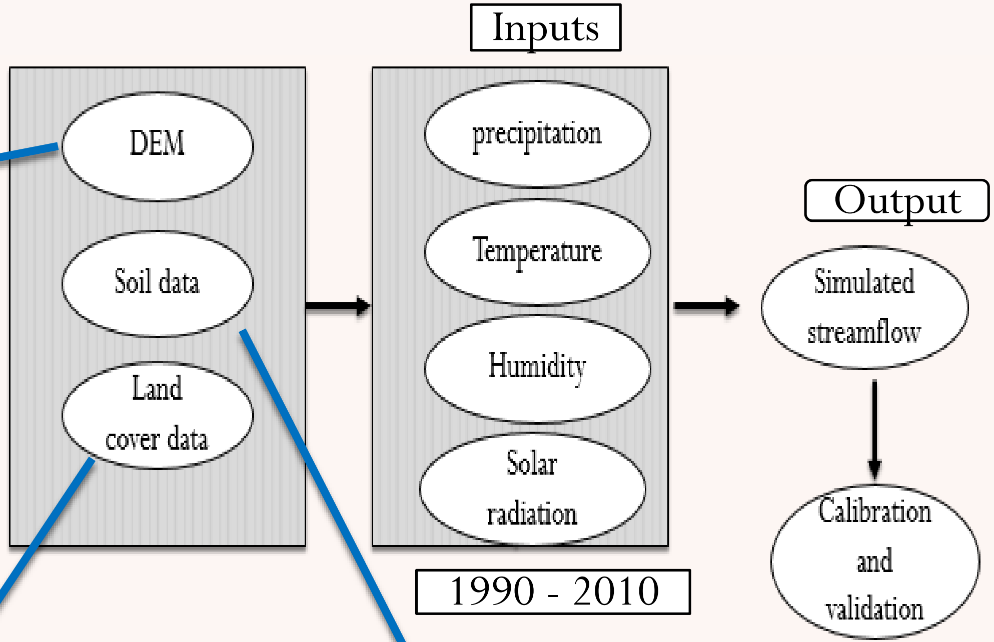
$$NS = 1 - \left[\frac{\sum_{i=1}^{n}\left(Q_{obs,i} - Q_{sim,i}\right)^2}{\sum_{i=1}^{n}\left(Q_{obs,i} - \bar{Q}_{obs}\right)^2}\right]$$

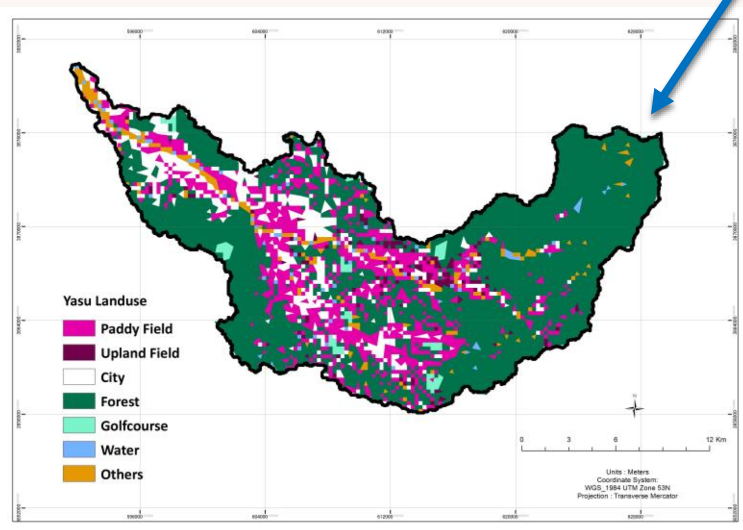
$Q_{obs,i}$ =observed streamflow
$Q_{sim,i}$ =simulated streamflow
$\bar{Q}_{obs}$ =mean of observed streamflow
$\bar{Q}_{sim}$ = mean of simulated stream flow
n = total number of observation

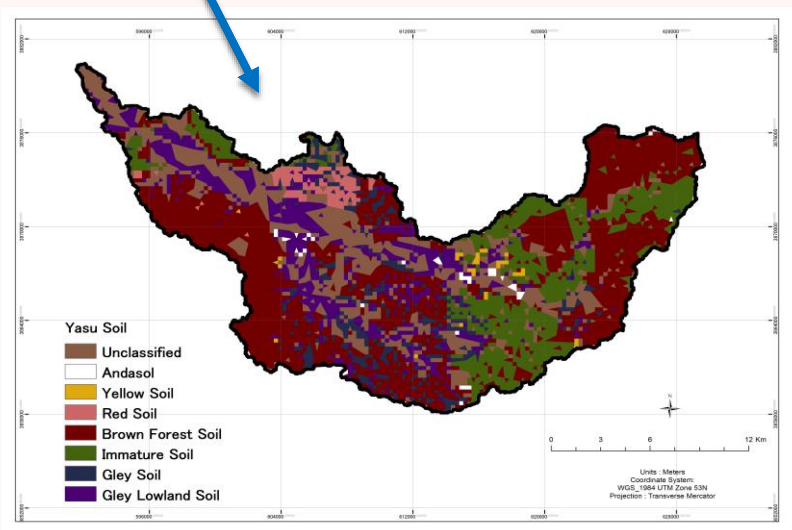
Application

SWAT model build up









Sensitivity analysis results of Monthly Streamflow

	SUFI-2			GLUE		
Parameter	**t-stat**	**p-value**	**Rank**	**t-stat**	**p-value**	**Rank**
R__CN2.mgt	37.947	7.6[illegible]E-195	1	41.551	9.94E-219	1
V__ALPHA_BF.gw	18.953	1.5[illegible]	2	17.982	9.94E-63	2
[illegible]	[illegible]69	[illegible]	[illegible]	[illegible]	6.33E-33	3
[illegible]	[illegible]51	[illegible]	[illegible]	[illegible]	1.89E-32	4
[illegible]	[illegible]79	[illegible]	[illegible]	[illegible]	6.01E-11	5
[illegible]	[illegible]49	[illegible]	[illegible]	[illegible]	1.49E-06	6
[illegible]	[illegible]22	[illegible]	[illegible]	[illegible]	3.93E-06	7
R__SOL_K(..).sol	2.3836	0.0173	8	4.1435	3.71E-05	8
V__GWQMN.gw	-1.966	0.0498	9	-3.488	0.000508	9
V__GW_REVAP.gw	-1.479	0.139	10	-1.866	0.0622	10
V__GW_DELAY.gw	-0.588	0.556	11	-1.836	0.0667	11
R__SOL_AWC(..).sol	-0.553	0.580	12	-0.886	0.375	12
V__REVAPMN.gw	-0.382	0.702	13	-0.543	0.587	14
A__ESCO.hru	-0.371	0.710	14	-0.471	0.637	15
V__SURLAG.bsn	-0.302	0.762	15	-0.722	0.470	13

A coefficient of a parameter divided by its standard error

P-value is given from Student's t distribution table

Sensitivity analysis results of Daily Streamflow

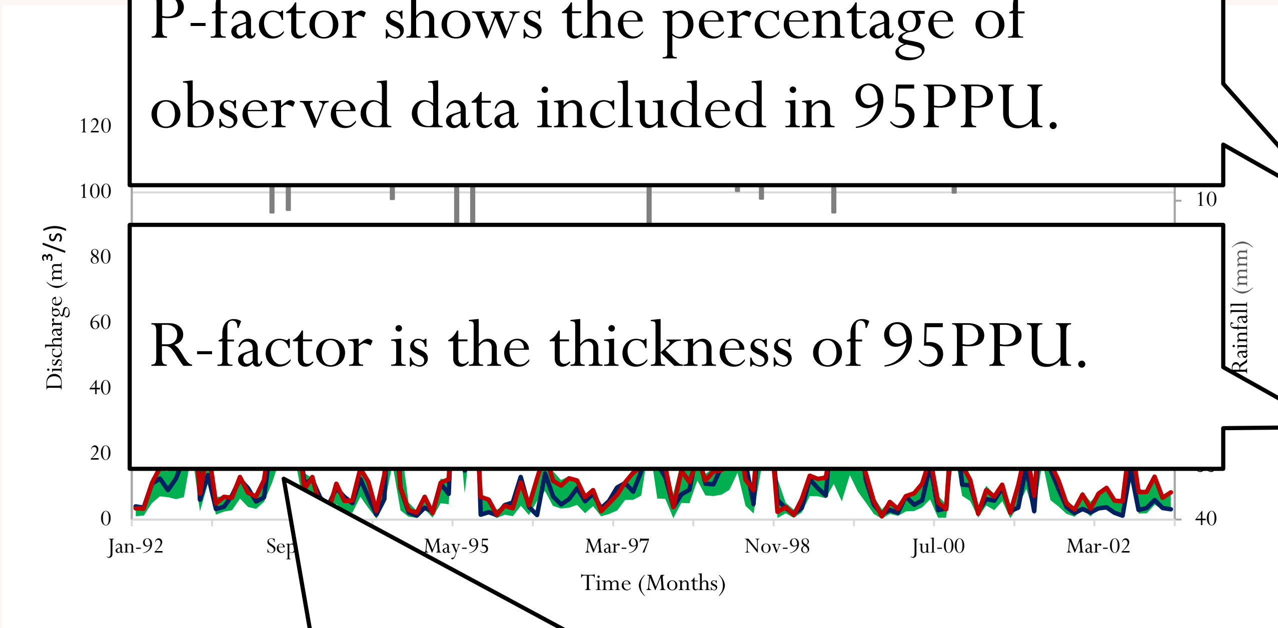
	SUFI-2			GLUE		
Parameter	t-stat	p-value	Rank	t-stat	p-value	Rank
R__CN2.mgt	13.47	4.04E-38	2	17.97	1.15E-62	4
V__ALPHA_BF.gw	18.97	1.13E-68	1	19.70	4.30E-73	3
V__SLSUBBSN.hru	-17.35	4.75E-59	4	-20.56	1.90E-78	2
V__HRU_SLP.hru	13.21	8.03E-37	5	16.60	8.47E-55	6
V__CH_K2.rte	-17.42	1.99E-59	3	-21.35	2.03E-83	1
V__CH_N2.rte	-5.158	3.02E-07	7	-6.646	4.99E-11	7
V__OV_N.hru	-12.46	3.28E-33	6	-17.96	1.36E-62	5
R__SOL_K(..).sol	0.715	0.474	10	1.552	0.120	9
V__GWQMN.gw	0.782	0.433	9	-1.364	0.172	10
V__GW_REVAP.gw	0.493	0.621	13	0.656	0.511	14
V__GW_DELAY.gw	0.628	0.529	12	-0.863	0.388	12
R__SOL_AWC(..).sol	-0.383	0.701	15	-0.412	0.680	8
V__REVAPMN.gw	0.436	0.662	14	-0.881	0.378	13
A__ESCO.hru	-0.711	0.477	11	-0.462	0.644	15
V__SURLAG.bsn	-1.278	0.201	8	-1.068	0.285	11

Fitted value

			Fitted Value			
Parameter Name	Min_value	Max_value	SUFI-2 Daily	GLUE Daily	SUFI-2 Monthly	GLUE Monthly
R__CN2.mgt	-0.025	0.5	0.404	0.432	0.493	0.342
V__ALPHA_BF.gw	0	1	0.870	0.885	0.325	0.377
V__SLSUBBSN.hru	10	150	33.310	24.384	28.270	16.827
V__HRU_SLP.hru	0	1	0.725	0.404	0.821	0.616
V__CH_K2.rte	0	150	88.725	67.53	64.275	54.644
V__CH_N2.rte	0.001	0.3	0.284	0.191	0.122	0.211
V__OV_N.hru	0.01	30	11.331	11.719	4.433	15.861
R__SOL_K(..).sol	-0.25	0.25	-0.067	-0.055	-0.036	0.127
V__GWQMN.gw	0	5000	4857.5	413.377	4127.5	990.442
V__GW_REVAP.gw	0.02	0.2	0.096	0.030	0.056	0.167
V__GW_DELAY.gw	0	500	62.750	275.576	5.750	341.898
R__SOL_AWC(..).sol	-0.25	0.1	-0.161	-0.064	0.034	0.038
V__REVAPMN.gw	0	500	20.75	208.58	173.25	375.791
A__ESCO.hru	0	1	0.733	0.732	0.742	0.413
V__SURLAG.bsn	0.5	5	1.208	0.710	0.583	3.278

Monthly calibration hydrograph

GLUE



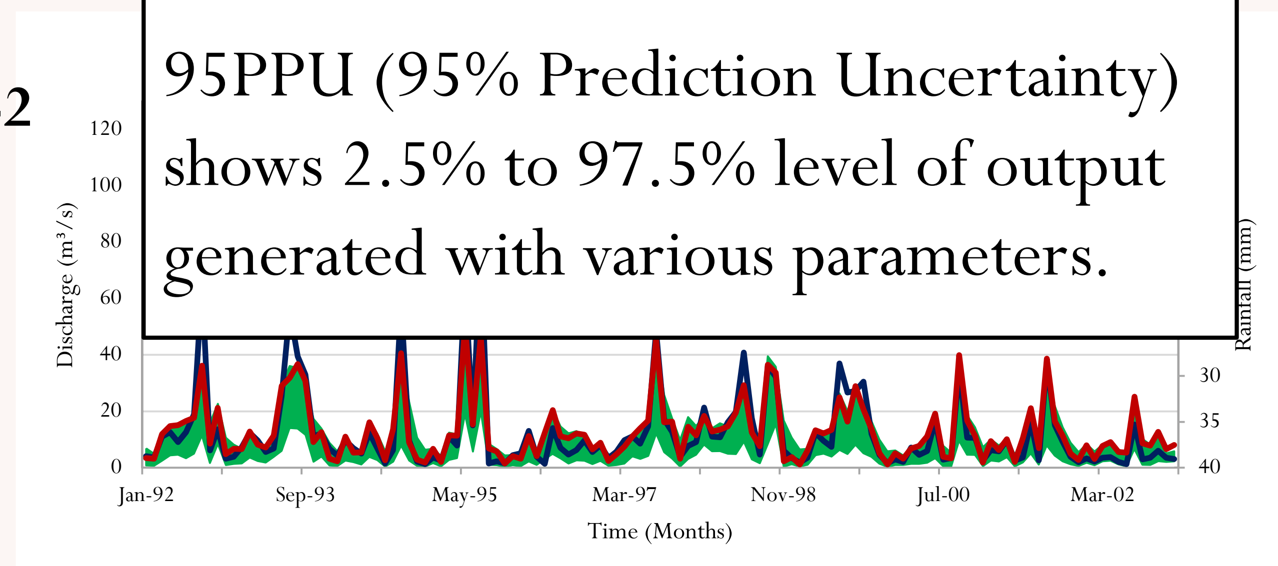
P-factor shows the percentage of observed data included in 95PPU.

R-factor is the thickness of 95PPU.

R^2=0.85
NS=0.82
P-factor=0.74
R-factor=0.58

SUFI-2

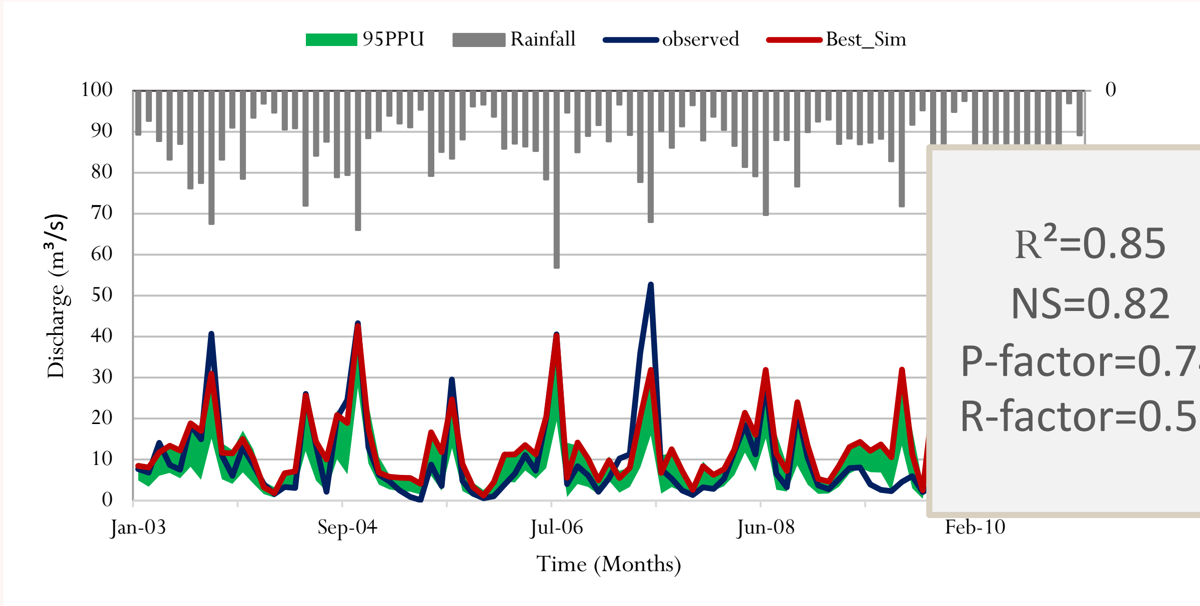
95PPU (95% Prediction Uncertainty) shows 2.5% to 97.5% level of output generated with various parameters.



R^2=0.85
NS=0.82
P-factor=0.86
R-factor=0.77

Monthly validation hydrograph

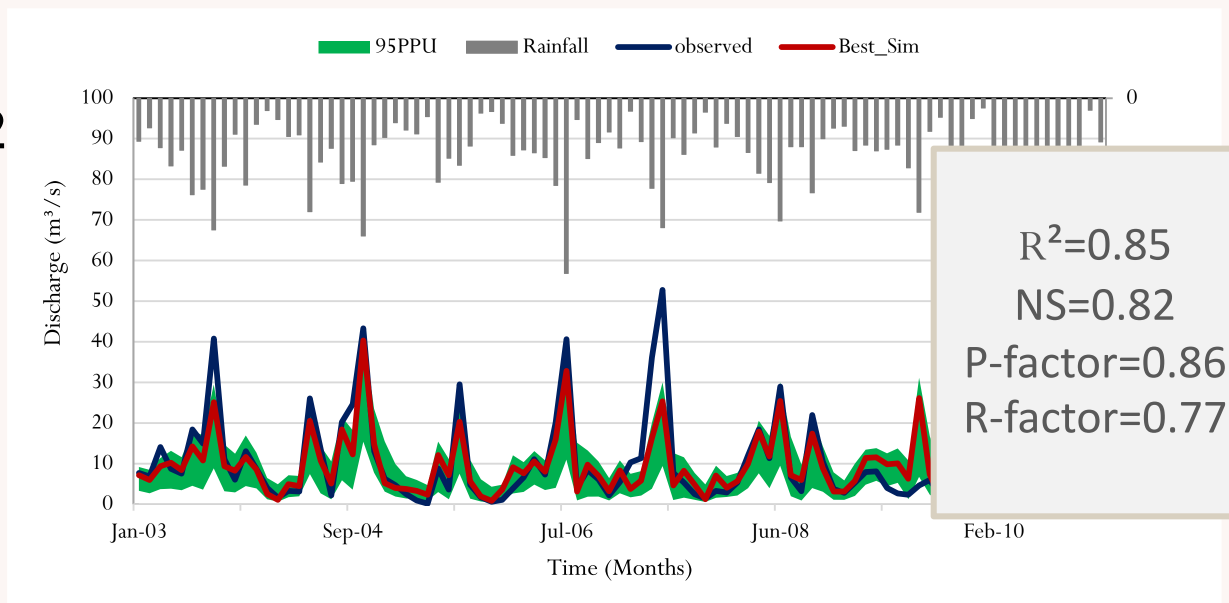
GLUE



R^2=0.85
NS=0.82
P-factor=0.74
R-factor=0.58

R^2=0.64
NS=0.63
P-factor=0.66
R-factor=0.78

SUFI-2

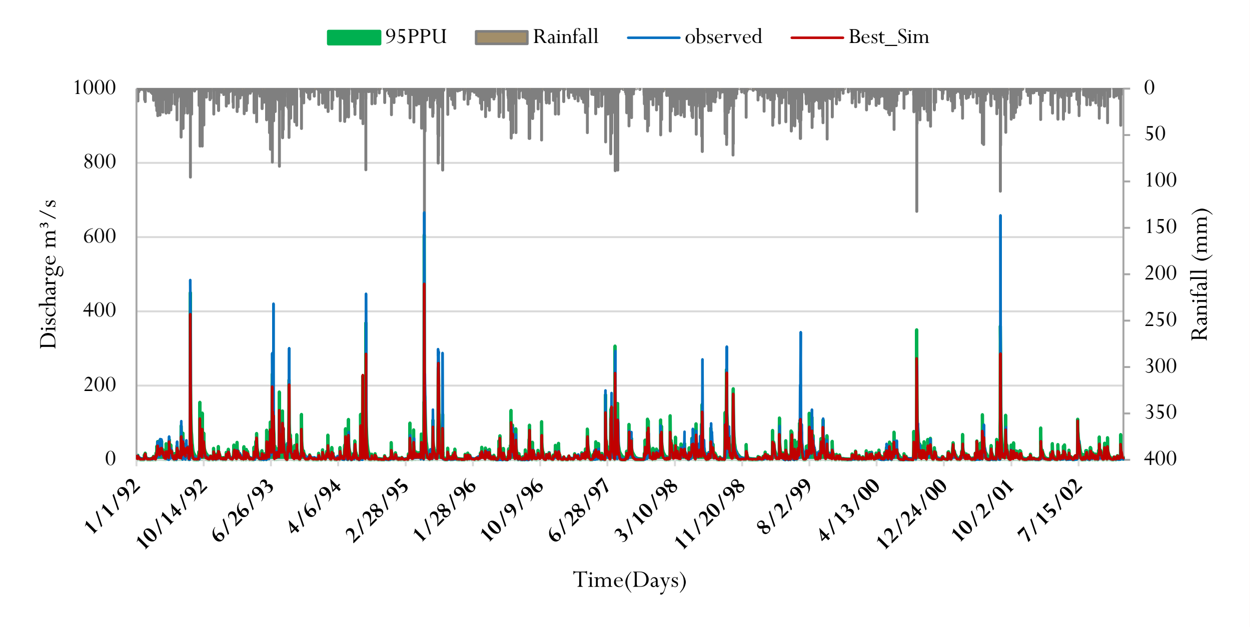


R^2=0.85
NS=0.82
P-factor=0.86
R-factor=0.77

R^2=0.63
NS=0.62
P-factor=0.82
R-factor=1.03

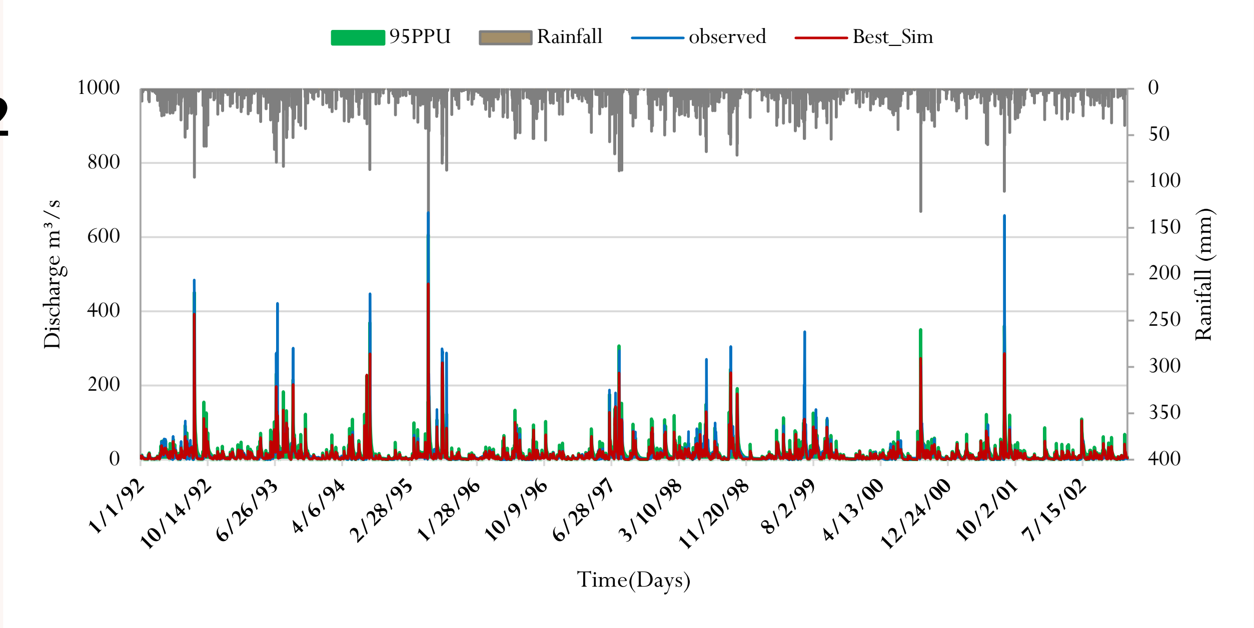
Daily calibration hydrograph

GLUE



R^2= 0.71
NS= 0.70
P-factor=0.80
R-factor=0.45

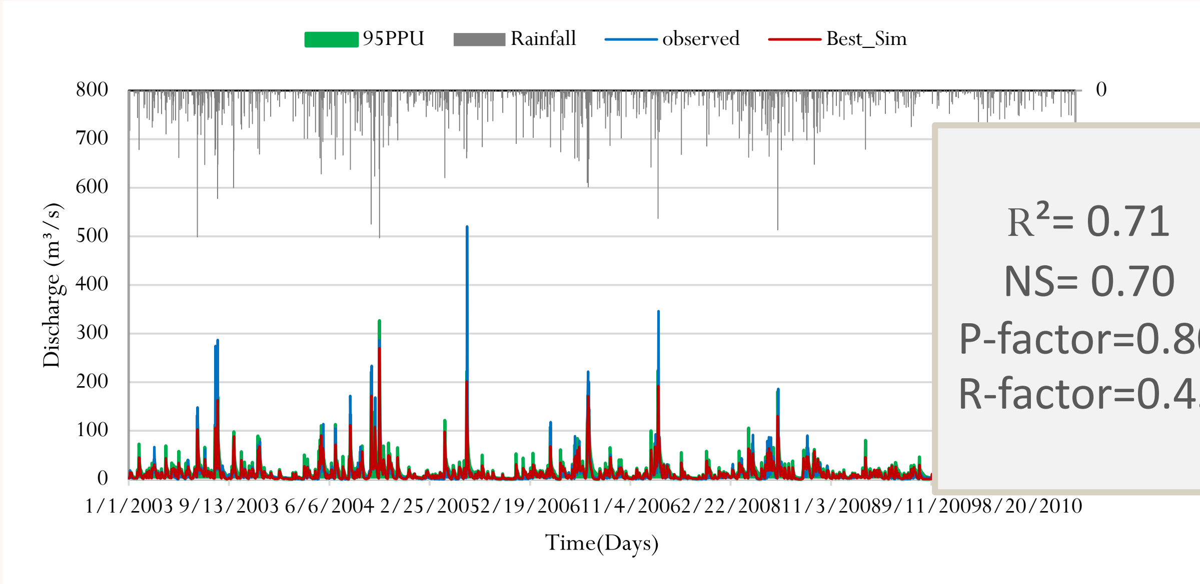
SUFI-2



R^2=0.71
NS=0.70
P-factor=0.90
R-factor=0.56

Daily validation hydrograph

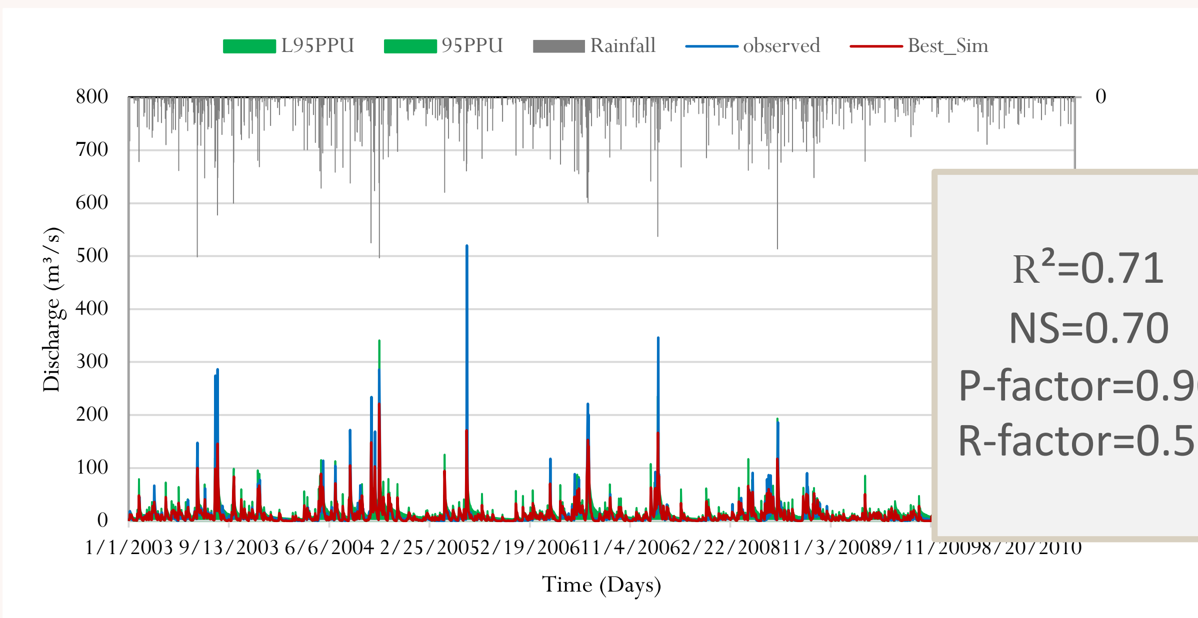
GLUE



R^2= 0.71
NS= 0.70
P-factor=0.80
R-factor=0.45

R^2=0.60
NS=0.59
P-factor=0.88
R-factor=0.58

SUFI-2



R^2=0.71
NS=0.70
P-factor=0.90
R-factor=0.56

R^2=0.62
NS=0.61
P-factor=0.94
R-factor=0.71

Conclusion

- This study provided an approach for streamflow simulation based on SWAT model in a Japanese relatively small and steep basin.
- Sensitivity analysis, calibration, validation and uncertainty analysis were carried out.
- Results revealed parameters' rank on sensitivity based on optimization techniques (SUFI-2 and GLUE) in daily and monthly stream flows.
- Monthly period yielded high NS and R^2 as compared to daily period.
- Uncertainty range was larger in SUFI-2 as compared to GLUE for both daily and monthly period during calibration and validation.

Future Plan

- To introduce artificial structures such as dams, irrigation ponds, channel network, head works, and pumping stations into SWAT model.