Application of the SWAT Model to the Hii River Basin, Shimane Prefecture, Japan

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Introduction

- Impact assessments of land use change, population growth / decrease and watershed development to water quantity and quality are one of the most important topics in a basin.

- Integrated water management is very important for conservation and sustainable use of its resources

In recent years,

water quality in lakes are tried to improve until under environmental standard by emission control of pollutant loads to a lake and rivers through putting an adequate sewage system in place and development of laws

However

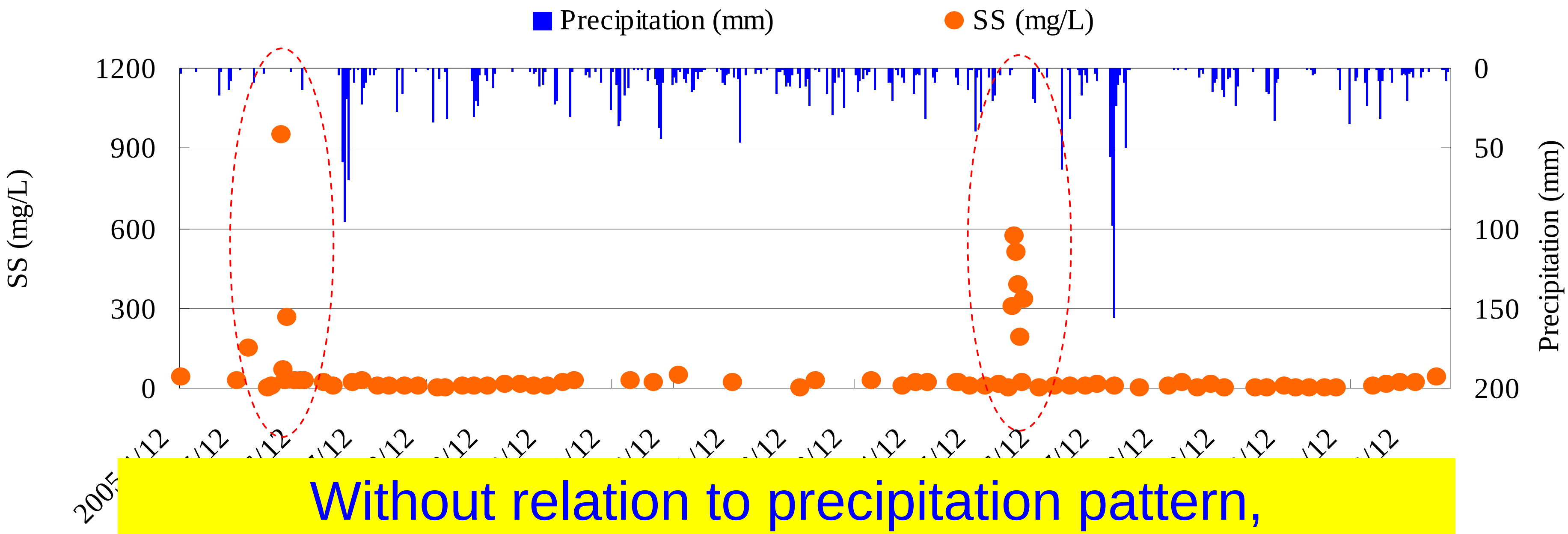
Water quality in lakes have not been improved well as we expected

Introduction

One of the reasons is considered to be pollutant loads discharged from non-point sources

- Water management: depending on farmers (relatively loose management)
- Fertilizer application: accumulation of unused nutrients in soil

By precipitation and drainage water, pollutant loads flow to rivers and a lake



Without relation to precipitation pattern, high concentrations of drainage water were observed

Preparation for transplanting young rice plants (for example)

Drain outlet

Introduction

There are lakes called Lakes Shinji and Nakaumi where have not been improved water quality well in Shimane prefecture

Average water quality at the center of lakes (2005)

	COD (< 3.0mg/L)	TN (< 0.4mg/L)	TP (<0.03mg/L)
Lake Shinji	4.8□4.4□	0.55	0.036
Lake Nakaumi	4.3□3.8□	0.42	0.034

(Shimane Prefecture: http://www.pref.shimane.lg.jp/)

As the Lake Shinji and Lake Nakaumi have been designated as one of the Wetlands of International Importance by the Ramsar Convention in November 2005, It is very necessary to improve water quality environment

Objective

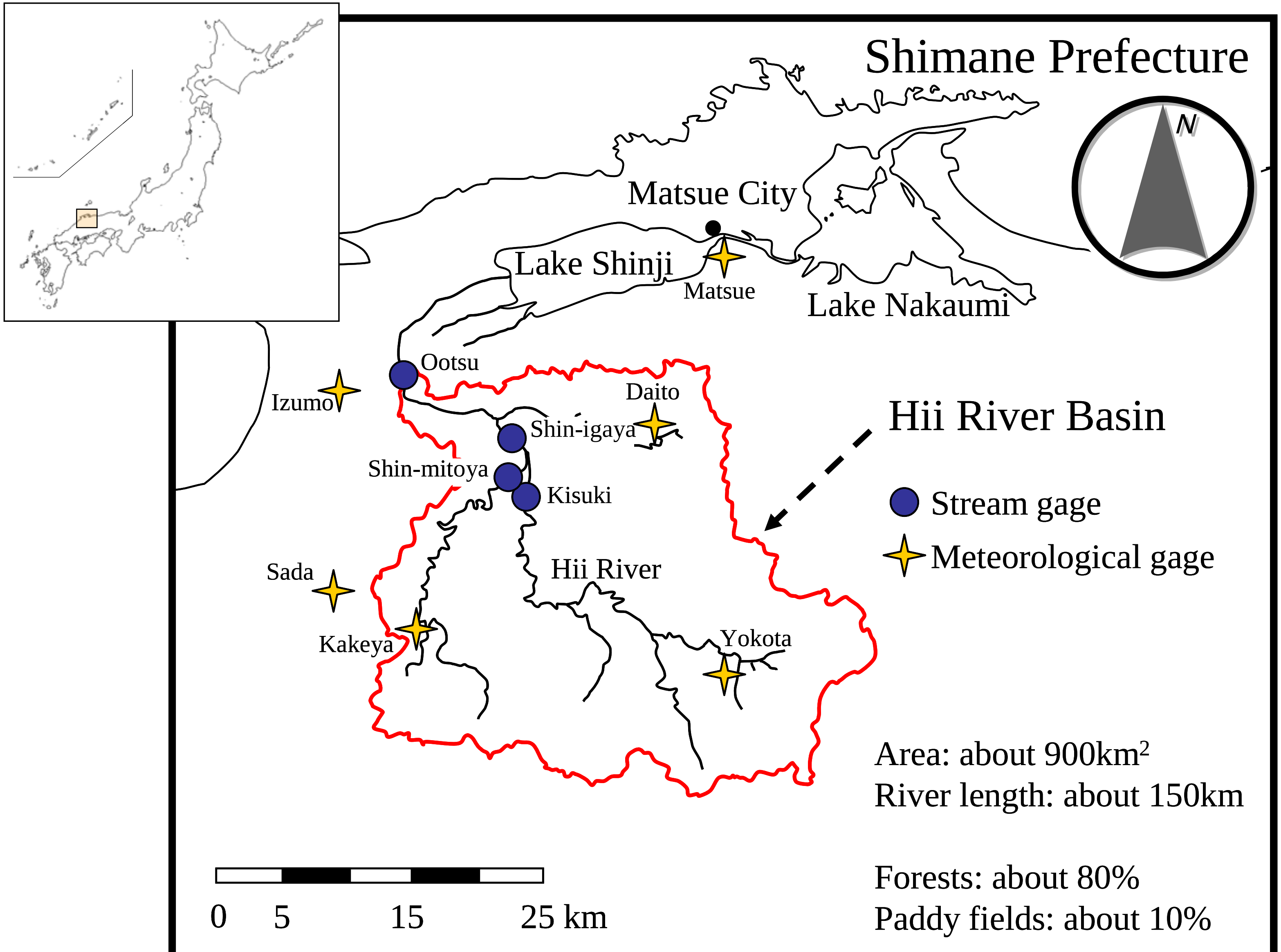
When considering watershed management and improvement of water environment in lakes, both information of lakes and rivers will be necessary

A lot of study:
Water quality environments in Lakes Shinji and Nakaumi

Few studies:
Runoff analysis and quantitative analysis of pollutant loads

Thus, we tried to represent stream flow in the Hii River basin by the SWAT model as a first step of water environment management

Study area



As the Hii River dominates about 75 % of watershed area flowing into the Lake Shinji, it is considered that water quality and quantity of the river will affect the Lake a lot.

Methodology

Application of the SWAT model:

from 1986 to 2005 by daily time step
(we paid attention to discharge of the river)

The Hii River basin:

divided by four sub basins according to locations of stream gages in the basin (Ootsu, Shin-igaya, Shin-mitoya, and Kisuki)

The parameters:

calibrated from 1993 to 1996
validated from 1986 to 1992 and from 1997 to 2005

Auto calibration:

10 parameters selected by ranking of the sensitivity analysis
(targeted to all sub basins using daily discharge data)

Range and optimal values of SWAT2003 calibration parameters

Parameter name	Lower bound	Upper bound	Optimal value	Imet
CANMX: Maximum canopy storage (mmH_2O)	0.0	10.0	0.009	1
ALPHA_BF: Baseflow alpha factor (days)	0.0	1.0	0.75	1
SOL_AWC: Available water capacity of the soil layer (mmH_2O/mm soil)	-0.040	0.040	0.04	2
SOL_Z: Depth from soil surface to bottom of layer (mm)	-50.0	600.0	588.2	2
CH_K2: Effective hydraulic conductivity in main channel alluvium (mm/hr)	0.0	150.0	150	1
SMFMX: Melt factor for snow on June 21 (mmH_2O/°C-day)	2.0	8.0	2.09	1
GWQMN: Threshold depth of water in the shallow aquifer required for return flow to occur (mmH_2O)	0.0	5000.0	0.35	1
CN2: Initial SCS runoff curve number for moisture condition II	-8.0	8.0	-6.6	2
ESCO: Soil evaporation compensation factor	0.0010	1.0000	0.89	1
SLOPE: Average slope steepness (m/m)	0.0	0.6	0.0002	1

Note: Imet means variation methods available in auto calibration (1: Replacement of initial parameter by value, 2: adding value to initial parameter)

Input data description

The SWAT requires:

Meteorological data	Daily precipitation Maximum and minimum air temperature Wind speed Relative humidity Solar radiation data

Since some holes were present in the climate data, the weather generator included in SWAT was used

Spatial data	A digital elevation map (DEM) Land cover GIS data Soil GIS data
Observed data	River discharge data

Meteorological data

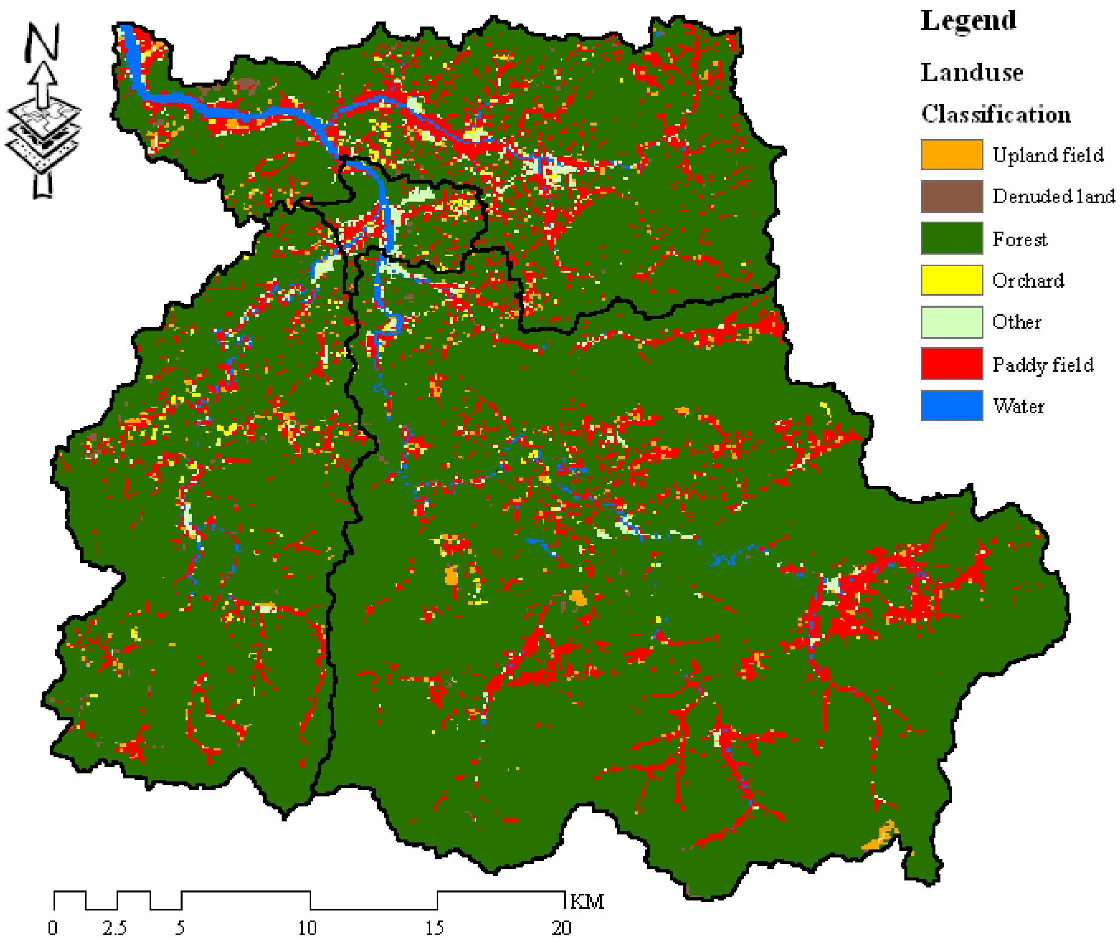
Average annual precipitation and climatic variables from 1985 to 2005 at each gage

Gage name	EL. (m)	Annual Precip. (mm)	Max. Air temp. (deg. C)	Min. Air temp. (deg. C)	Wind speed (m/s)	Relative humidity (%)	Solar radiation (calculated) (MJ/m^2)
Matsue	16.9	-	-	-	-	75.6 (10.0)	-
Izumo	20	1726	18.9 (8.3)	10.3 (8.1)	2.2 (1.2)	-	11.1 (7.5)
Daito	56	1778	-	-	-	-	-
Sada	100	2072	-	-	-	-	-
Kakeya	215	2046	18.0 (9.0)	8.8 (8.3)	1.3 (0.7)	-	-
Yokota	369	1765	17.2 (9.3)	7.5 (8.8)	1.2 (0.7)	-	-

Note: The values in the parenthesis indicate a standard deviation

Meteorological data was obtained from the Japan Meteorological Agency (JMA: http://www.jma.go.jp/jma/index.html).

Land use GIS data



The data was obtained from the National-Land Information Office in Ministry of Land, Infrastructure and Transport Government of Japan (MLIT)

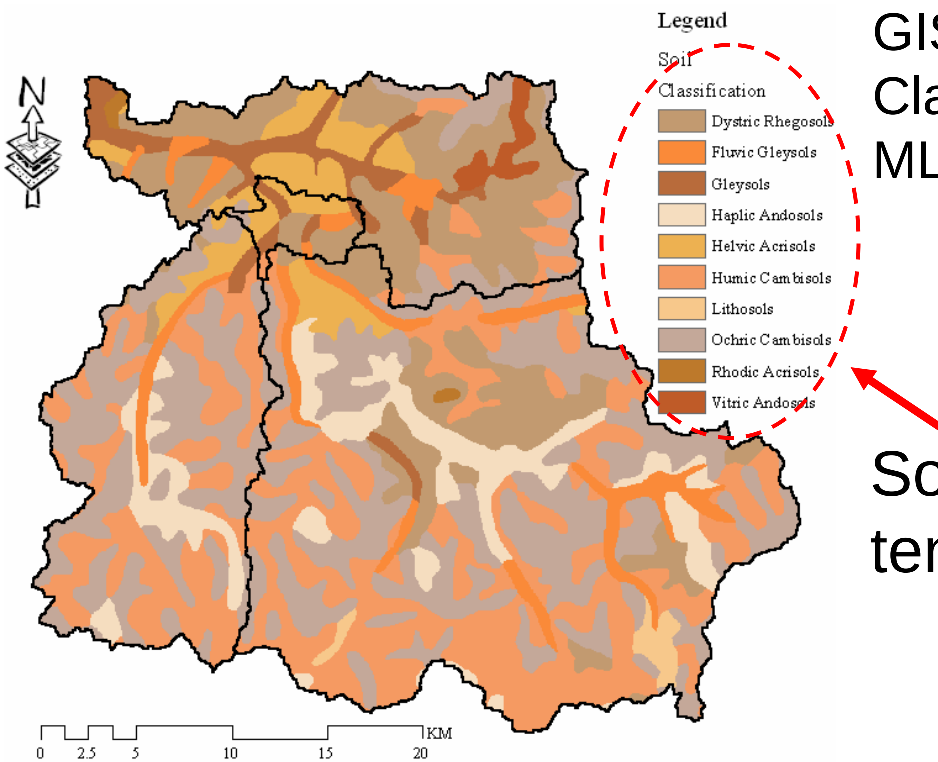
Land use GIS data

The land uses in each sub basin are almost very similar and impartial. Forest area changes from 59 % to 87 % and paddy fields area does from 9 % to 18 % spatially

Area and ratio of major land use in each sub basin

Gage name	Sub basin No.	Drainage area (Km^2)	Sub basin			
			Area (Km^2)	Forests (%)	Rice fields (%)	Upland Fields and Orchard (%)
Ootsu	Sub 1	914.4	183.9	74	16	3
Shin-igaya	Sub 2	730.5	14.1	59	18	5
Shin-mitoya	Sub 3	206.8	206.8	86	9	3
Kisuki	Sub 4	509.6	509.6	87	10	2

Surface soil GIS data



Soil type data was clipped from a soil map GIS data in 1:500,000 Fundamental Land Classification Survey prepared by the MLIT

Soil type was categorized as ten groups of fourteen soils

Internal data of each soil such as the number of layers, soil depth and phsico-chemical properties was prepared based on soil profile in soil map and literature data

Model performance evaluation

The swat model was calibrated and validated using observed discharge data

To evaluate the model performance:

The coefficient of determination (R^2)
Nash-Sutcliffe Index (*NSI*)

$$NSI = 1.0 - \left(\frac{\sum_{i=1}^{n} (Q_{obs,i} - Q_{cal,i})^2}{\sum_{i=1}^{n} (Q_{obs,i} - \overline{Q}_{obs})^2} \right)$$

(Nash-Sutcliffe Index)

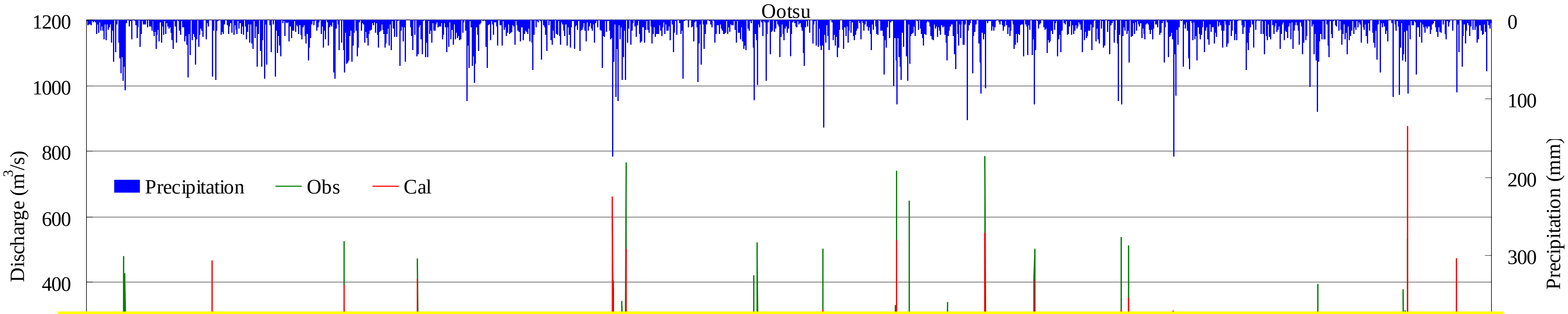
Simulated result

The model was applied to the Hii River basin, where has low densities of stream flow and climatic gages.

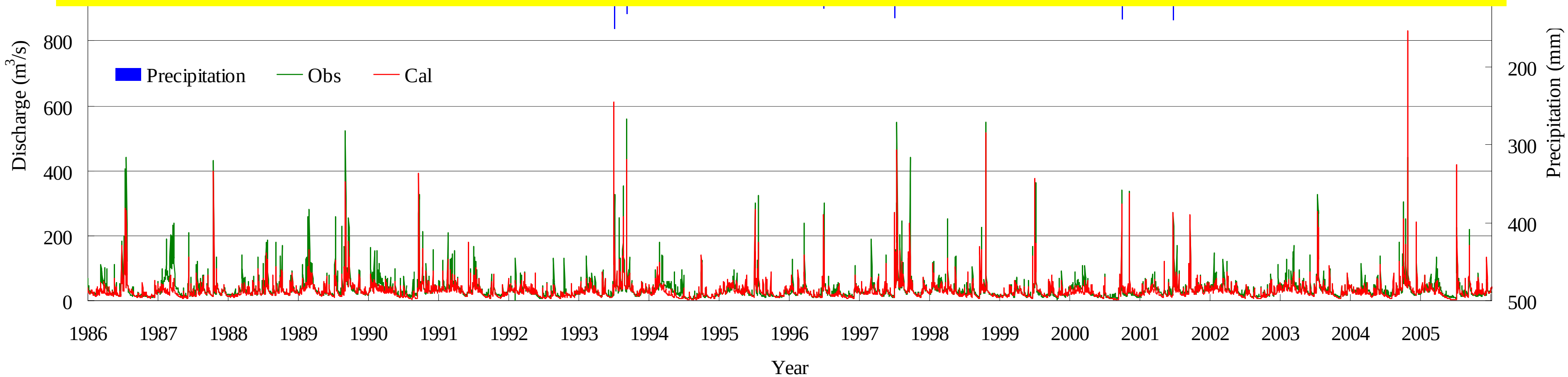
Simulated versus observed statistics for the Hii River calibration and validation

	Calibration period		Validation period			
	1993-1996		1986-1992		1997-2005	
	R^2	*NSI*	R^2	*NSI*	R^2	*NSI*
Sub 1	0.65	0.64	0.58	0.53	0.51	0.50
Sub 2	0.75	0.74	0.67	0.60	0.64	0.62
Sub 3	0.77	0.76	0.74	0.74	0.71	0.68
Sub 4	0.69	0.67	0.70	0.69	0.59	0.38

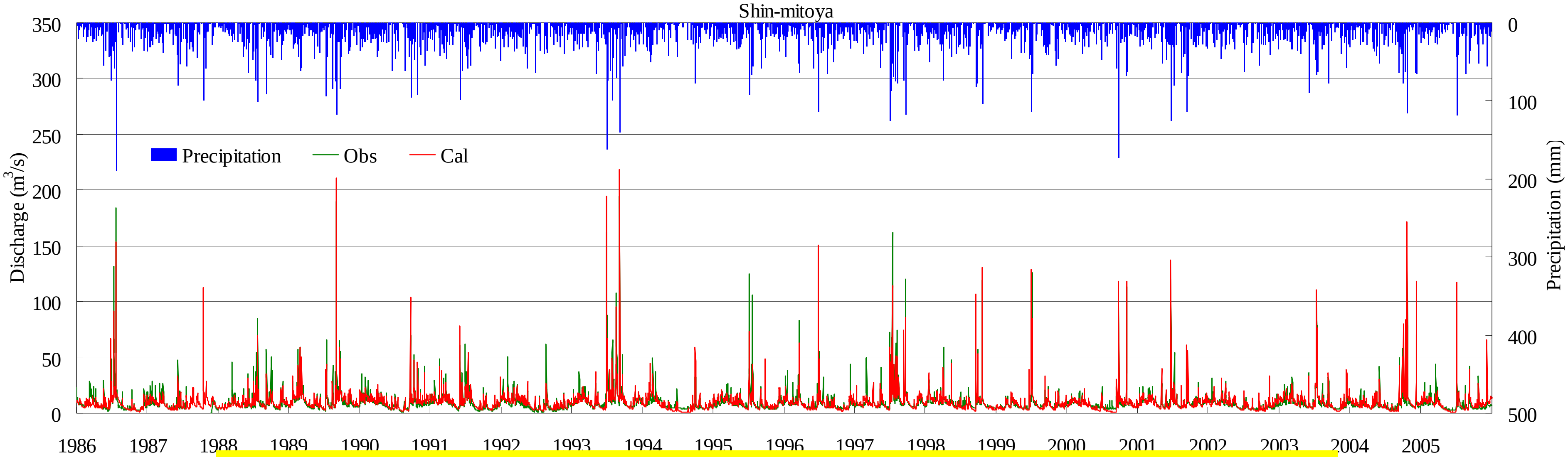
Hydrograph
-Sub basins 1 and 2-



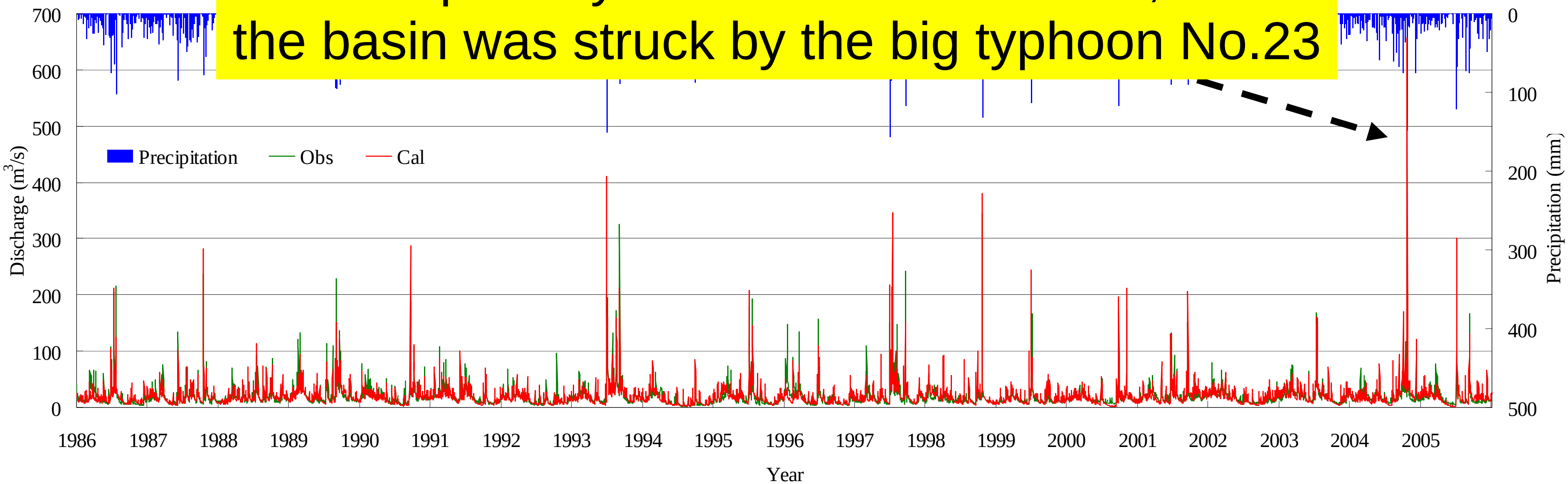
The both results of calibration and validation at each sub basin were represented fluctuations of discharge relatively well, though some peaks were overestimated.



Hydrograph
-Sub basins 3 and 4-



Especially on 20th October 2004,
the basin was struck by the big typhoon No.23



Water balance

Year	Precip. (mm)	Sur. flow (mm)	Lat. flow (mm)	Base flow (mm)	Perco. (mm)	Soil water (mm)	Actu. ET (mm)	Poten. ET (mm)	Water yield (mm)
Ave.	**1818**	**62**	**400**	**859**	**921**	**72**	**428**	**985**	**1321**

About 90 % of observed average discharge (1,473mm)

It is considered that base flow accounts for about 65 % and lateral flow does for about 30 % of water yield in the simulation

In this case, surface flow became quite small value
It must be a low representation of irrigation management
(there are channels for irrigation under present condition)

Conclusion

The SWAT performed well in simulating the general trends of river discharges at all sub basins over time for daily time intervals, though some discrepancies are exist

Thus, this study showed that the SWAT model can be used for Japanese mountainous river basin

However

For more accurate modeling of hydrology and simulating water quality component, a large effort will be needed to improve the quality of available information concerning soils, land use, agricultural activity, and climate of the basin

Thank you very much for you're attention