International SWAT Conference
25-27 June 2025, Jeju, South Korea

Soil & Water Assessment Tool SWAT

Evaluation of the Impact of Forest Cover Change in the Upper Kikuchi River Basin on Sediment and Nutrient Transport to the Ariake Sea, Japan

Yuko Nagano[*1], Jian Cui[*1], Rui Oba[*1], Hanae Yamamoto[*1], Shin-ichi Onodera[*2]

*1 Japan Forest Technology Association
*2 Graduate School of Advanced Science and Engineering, Hiroshima University, Japan

Motivation

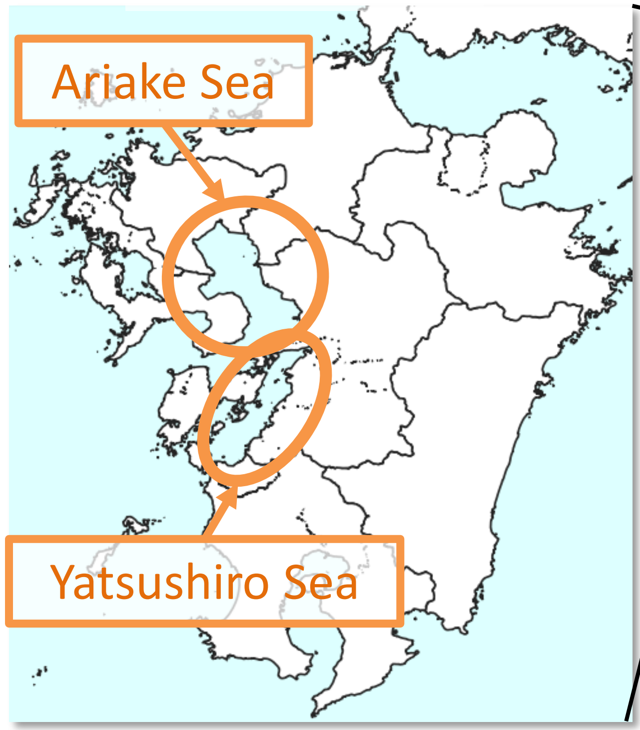
- Forests are expected to be one of the "Nature-based Solutions (NbS)" to address various social issues through their ecosystem services, and there is an increasing need to quantitatively evaluate them.

- Although the SWAT model is an effective tool for assessing hydrological responses to LULU changes in a watershed, some adjustments are said to be necessary for its application to forested watersheds.

Background and objectives

- In recent years, the Ariake Sea and Yatsushiro Sea, located in southern Japan, have been facing concerns about the deterioration of the marine environment and decline of fisheries.

- This study aims to clarify whether and how the forest ecosystems in a basin play a role for conservation and restoration of downstream marine environments using SWAT model.

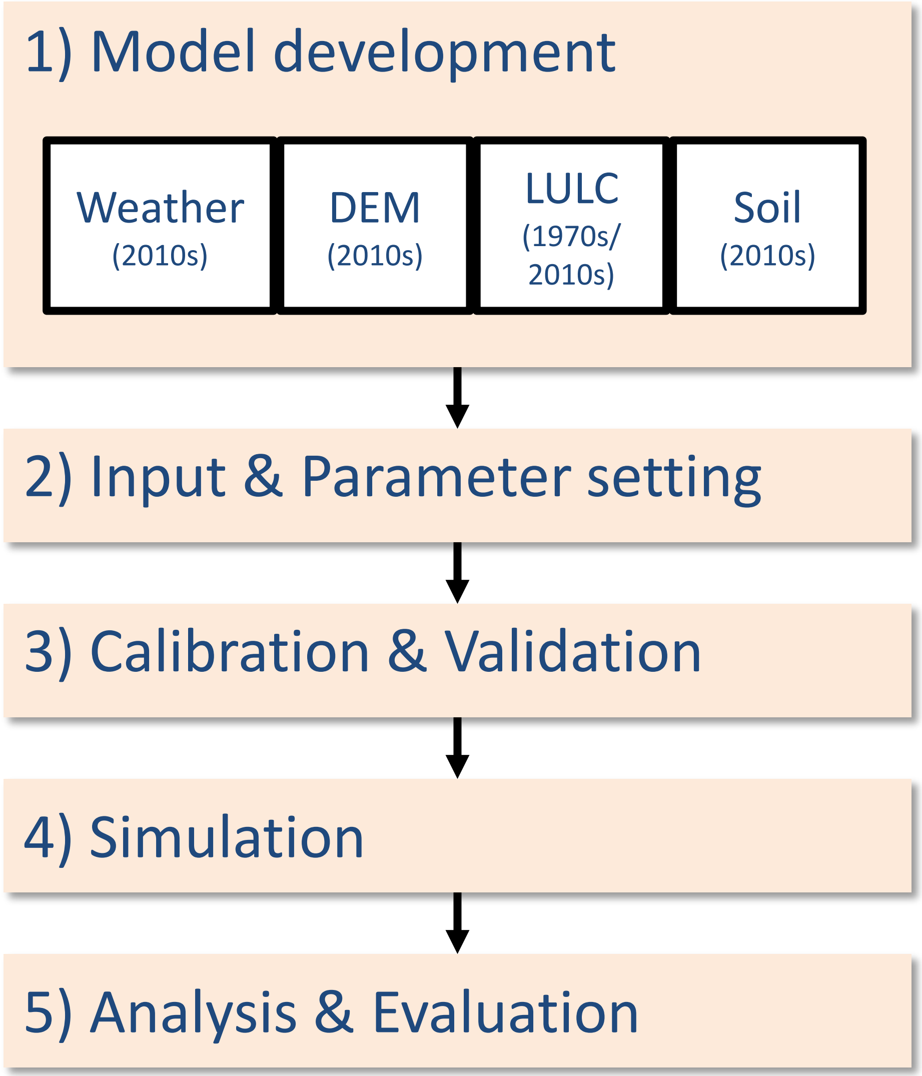


Red tide in the Yatsushiro Sea in 2021（©NNN）

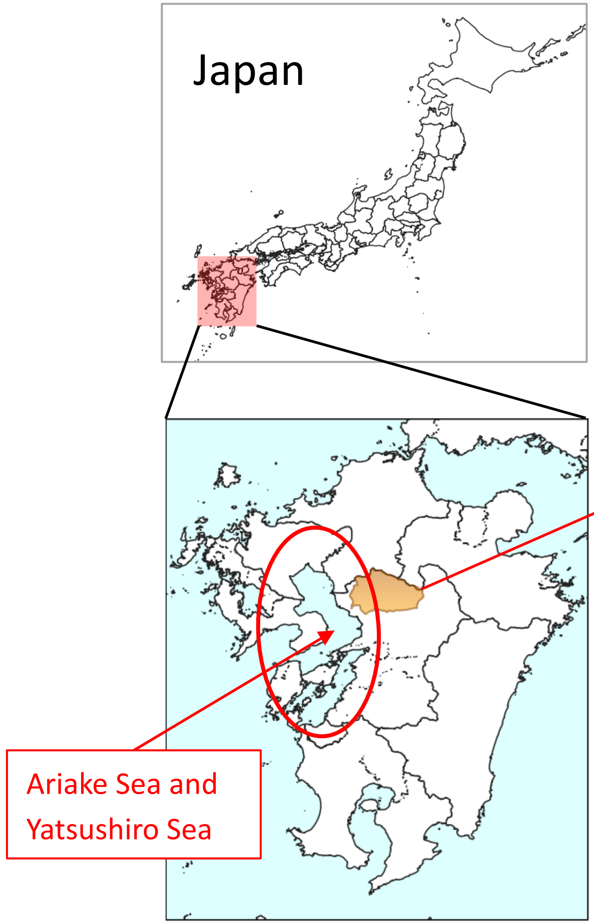
Methodology

- In this study, the impact of forest cover changes within a basin on sediment and nutrient transport to the Ariake Sea will be analyzed to know the ability of forest ecosystem services.

  - Develop two models that apply LULC at different times (2010s and 1970s).
  - Apply fitted parameter values for 2010s model to 1970s model.
  - Enhance the representation of Japanese forest ecosystems in a SWAT model.

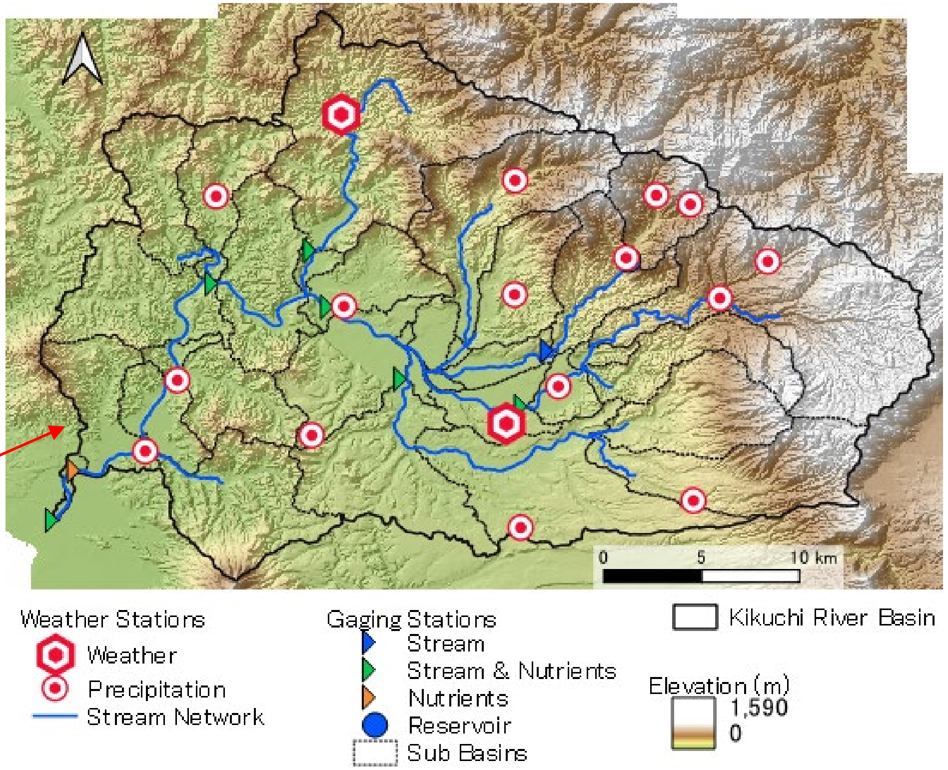


Study area description

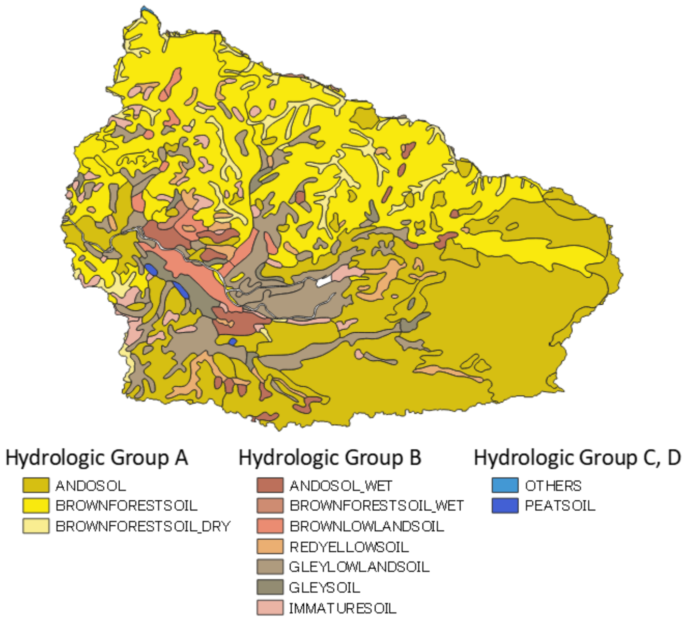


Kyusyu Region

■ Overview of Kikuchi River Basin



- Basin area: 996 km^2
- River length: 71km
- Population: Approx. 210,000 people
- Annual Precipitation: 2,300 mm
- Main land uses: Forest 50%, Agriculture 40%



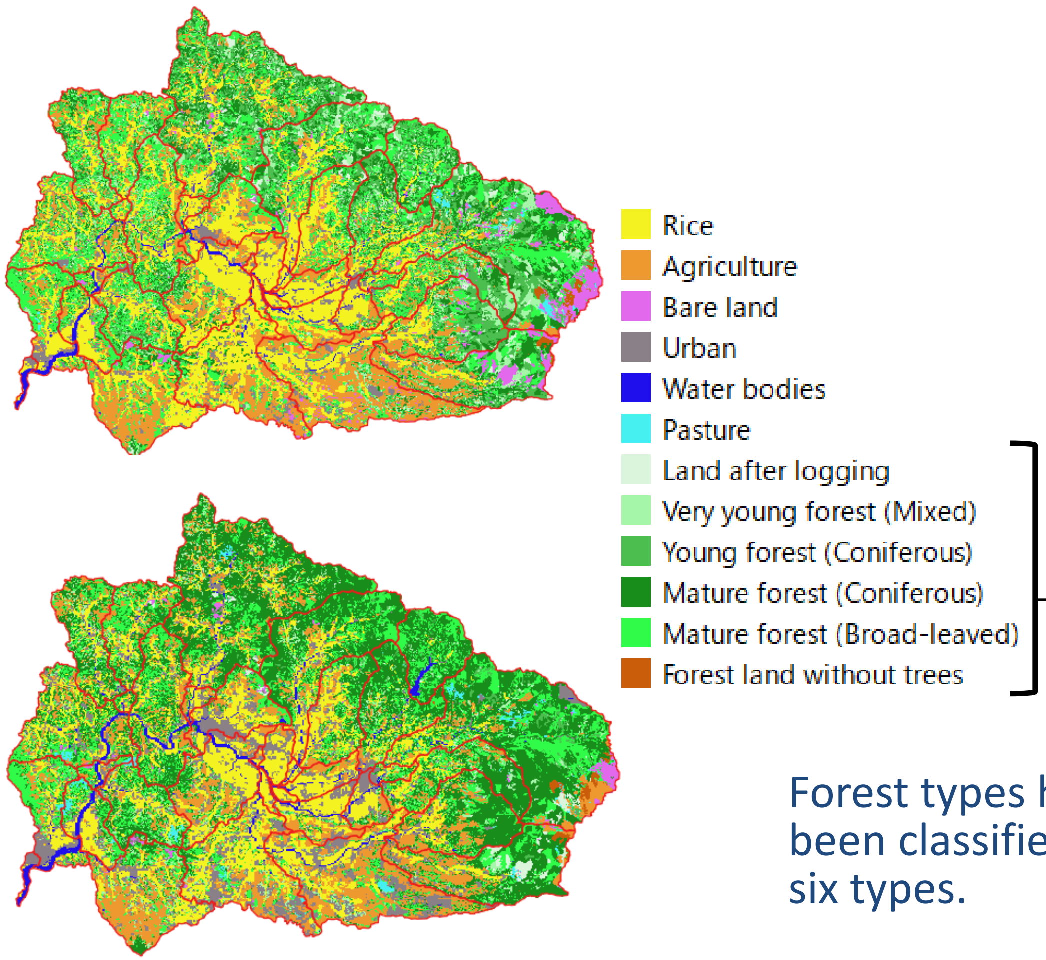
ANDOSOL and *BROWN FOREST SOIL*, classified as Hydrological Group A, are the dominant soil types and cover more than half area of the basin.

Study area description

■ LULC

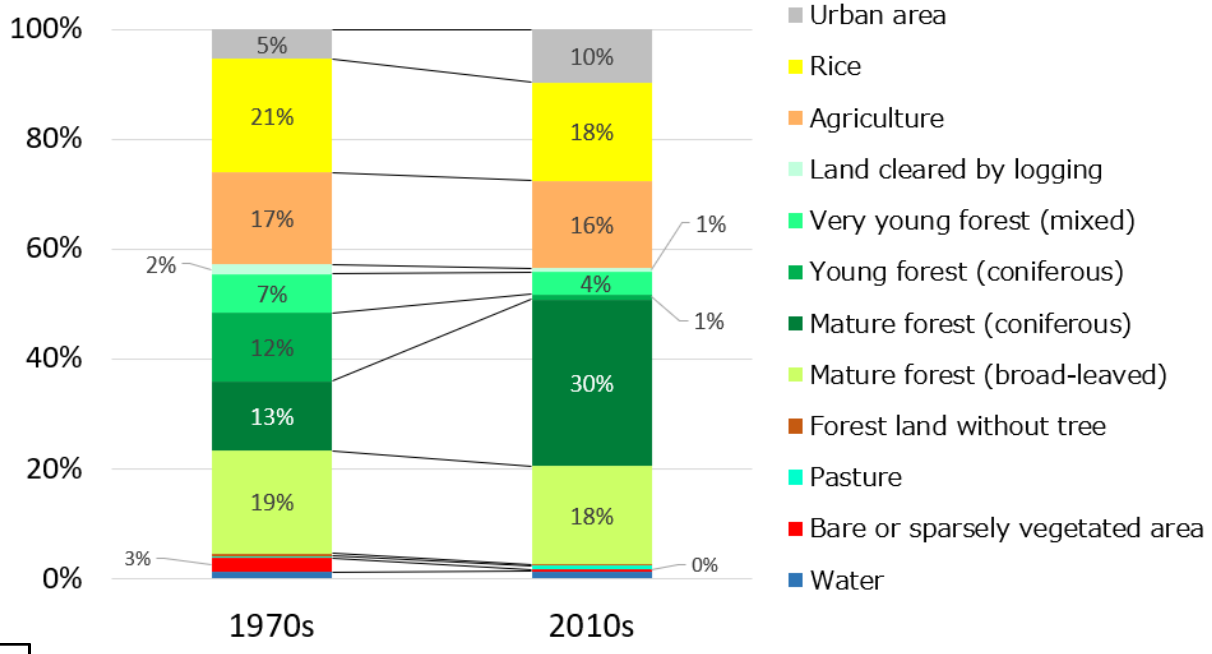
1970s

2010s



Forest types have been classified into six types.

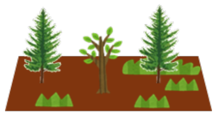
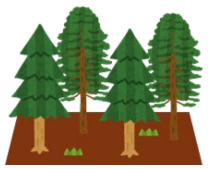
LULC Change from 1970s to 2010s

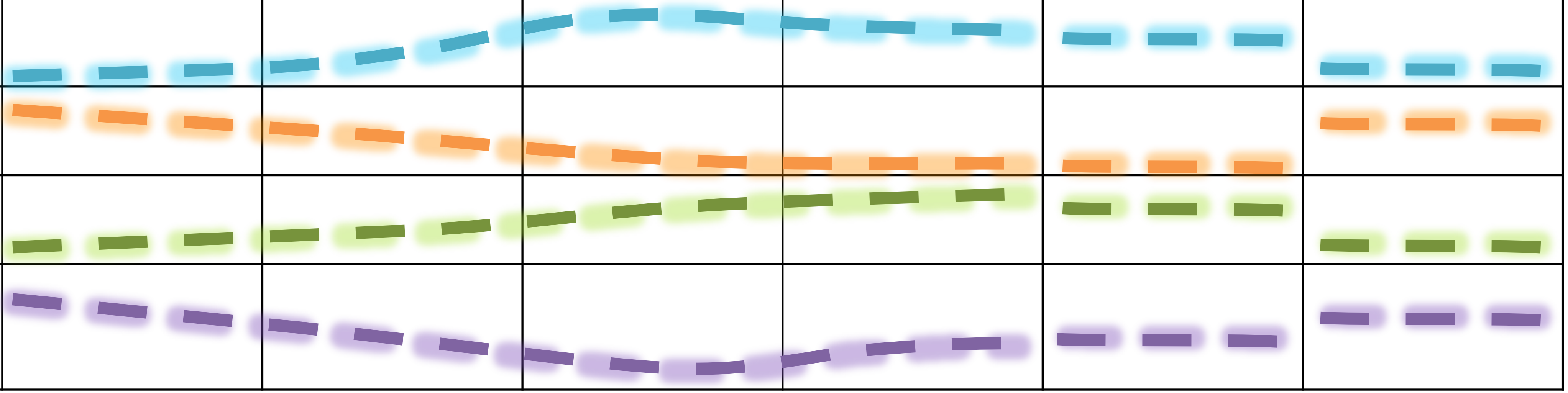


・Urban area	↑	5% → 10%
・Rice/Agriculture	↓	38% → 34%
・Young forest	↓	19% → 5%
・Mature forest	↑	13% → 30%
・Broad-leaf forest	→	stable

Adoption of forest-related parameters in SWAT

- Parameter adjustment policy considering hydrological behavior at each developmental stage of forest based on past research findings.

Forest developmental stage		 Land cleared by logging	 Very young forest (mixed)	 Young forest (coniferous)	 Mature forest (coniferous)	 Mature forest (broad-leaved)	 Forest land without trees
Age		0-3	4-10	11-20	21<	11<	-
Hydrological behavior	Evapo-transpiration						
	Surface/Sediment runoff						
	Soil infiltration /Percolation						
	Nitrogen transport to river						



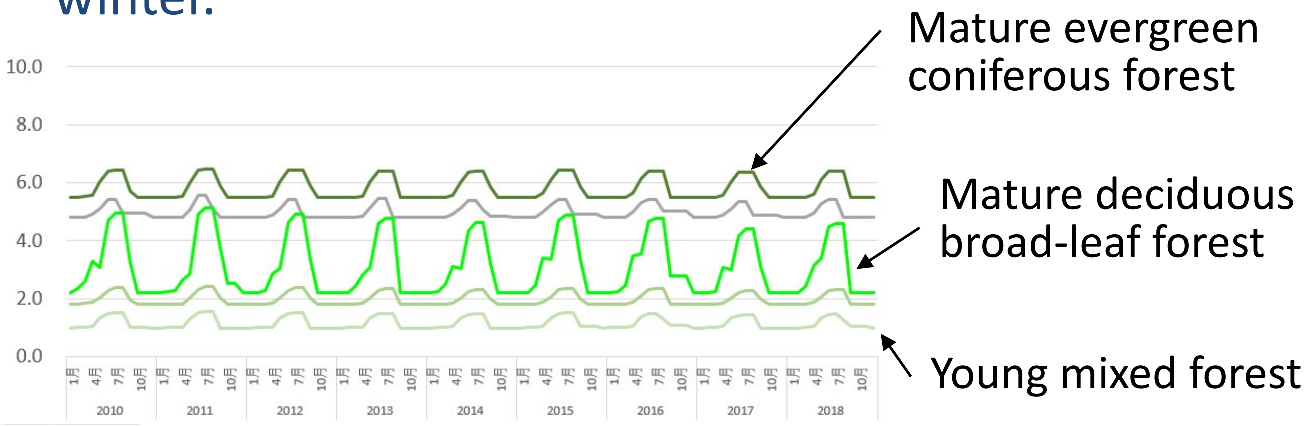
Adoption of forest-related parameters in SWAT

- Management operations

1) LAI

- *Crop database* does not include *LAI* for trees in a different development stage.
- The default *LAI* parameter values for evergreen forests does not represent actual tree phenology.

- Adjusted the *LAI* for evergreen coniferous forest as keeping the high value relatively high even during winter.



- For young to mature forests, LAI were set:
  - ✓ LAI_INIT: 1.3 – 5.5
  - ✓ BLAI: 5.2 - 6.5 (database)
  - ✓ ALAI_MIN: 1 – 5.5 (database)

MOD15A2H.061: Terra Leaf Area Index/FPAR 8-Day Global 500m(NASA) was referenced for the value of for forest as well as other LULC.

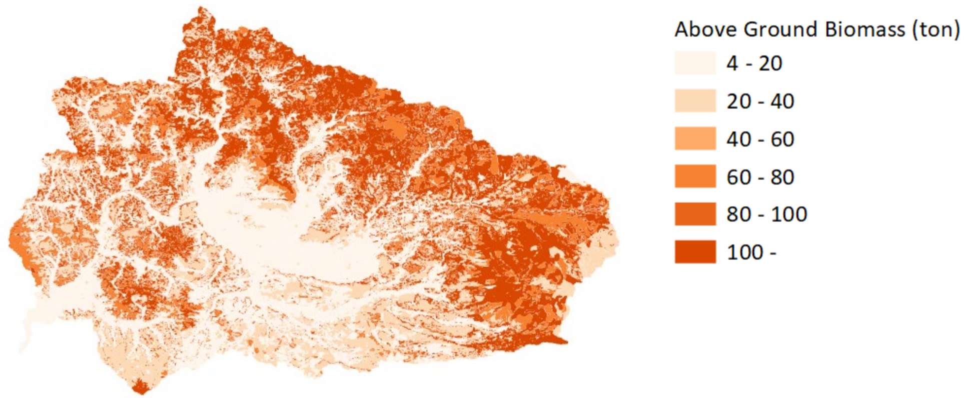
Adoption of forest-related parameters in SWAT

2) Biomass

- By default, parameter values for *BIO_INIT, BMX_TREES* for forests are not adequately set.

- Maximum value of the range for *BIO_INIT* is too small for forests in Japan.

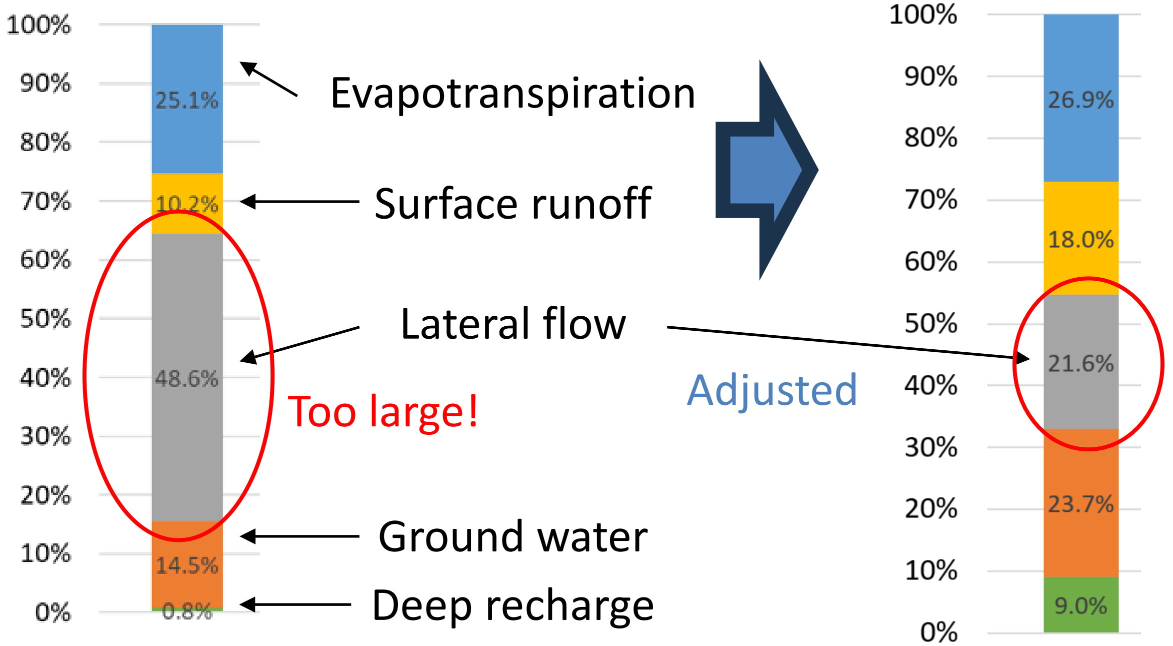
- Adopted biomass with reference to High-Resolution Land-Use and Land-Cover Map Products (JAXA).



- From young to mature forests, biomass-related parameters were set:
  - ✓ BIO_INIT: 25,000 - 90,000 kg/ha (database)
  - ✓ BMX_TREES: 30 – 126 ton/ha (database)

Adoption of forest-related parameters in SWAT

- Topography
  - Japanese forests are often located on steep slopes, which causes excessive lateral flow unless topographical adjustments are made.
  - *HRU_SLP*, *SLSOIL* were adjusted to obtain adequate lateral flow rate within the water balance.



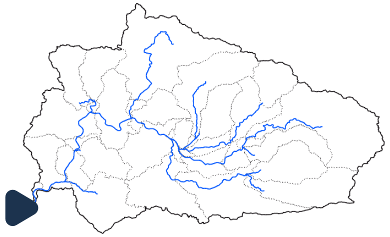
Adoption of forest-related parameters in SWAT

- Other fitted parameters

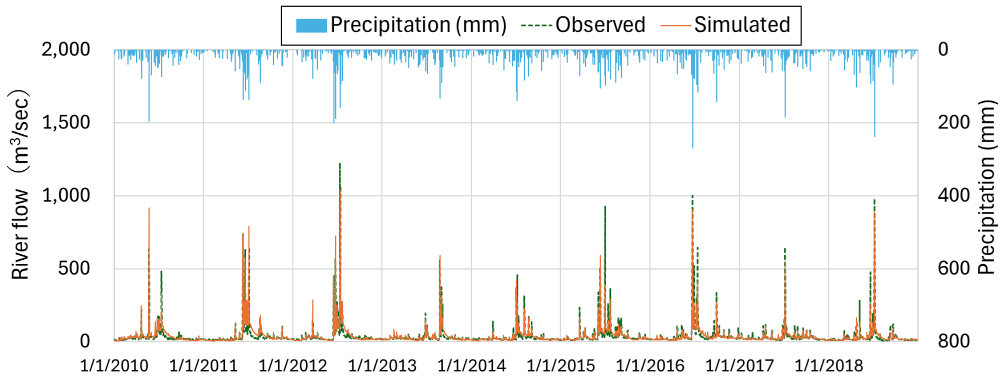
Table	Parameters	Defaut value	Fitted value	Definition
GW	ALPHA_BF	0.048[1/days]	0.562	Baseflow alpha factor.
	GWQMN	1000[㎜]	358.8	Threshold depth of water in the shallow aquifer required for return flow to occur.
	GW_REVAP	0.02	0.15	Groundwater "revap" coefficient.
	REVAPMN	750[㎜]	305	Threshold depth of water in the shallow aquifer for "revap" to occur.
	RCHRG_DP		0.31	Deep aquifer percolation fraction.
SOL	USLE_K1	-999(0-0.65)	R: -0.6422	USLE equation soil erodibility (K) factor.
	SOL_K1	-999 [mm/hr](0-200)	40-101	Saturated hydraulic conductivity for the soil layer 1.
	SOL_K2	-999 [mm/hr](0-200)	31-37	Saturated hydraulic conductivity for the soil layer 2.
	SOL_AWC1	0.032－0.35[㎜/hr]	0.22-0.50	Available water capacity of the soil layer 1.
	SOL_AWC2		0.45	Available water capacity of the soil layer 2.
	SOL_BD1		0.60-0.81	Moist bulk density for the soil layer 1.
	SOL_BD2		0.85-0.91	Moist bulk density for the soil layer 2.
MGT	CN2		44 - 82	SCS runoff curve number for moisture condition 2
HRU	SLSUBBSN	9-91[㎜]	R: 2.481	Average slope steepness.
	HRU_SLP		R: 0.9325 - 2.1775	Average slope steepness.
	SLSOIL		50 - 132	Average slope length.
	OV_N	0.01-0.15	0.1-0.61	anning's "n" value for overland flow.
	LAT_TTIME	0	17.67	Lateral flow travel time.
	CANMX	0[㎜]	1.41-6.16	Maximum canopy storage.
	ESCO	0.95	0.005 - 1.0	Soil evaporation compensation factor.
	EPCO	0.01-1	0.001 - 0.95	Plant uptake compensation factor.
RTE	CH_COV1	0 [ ](-0.05-0.6)	0.0272	Channel erodibility factor.
	CH_COV2	0 [ ](-0.001-1)	0.2145	Channel cover factor.
crop	GSI		0.0055 - 0.02	Max stomatal conductance (in drough condition).
	USLE_C	1	0.01-0.03	Min value of USLE C factor applicable to the land cover/plant.

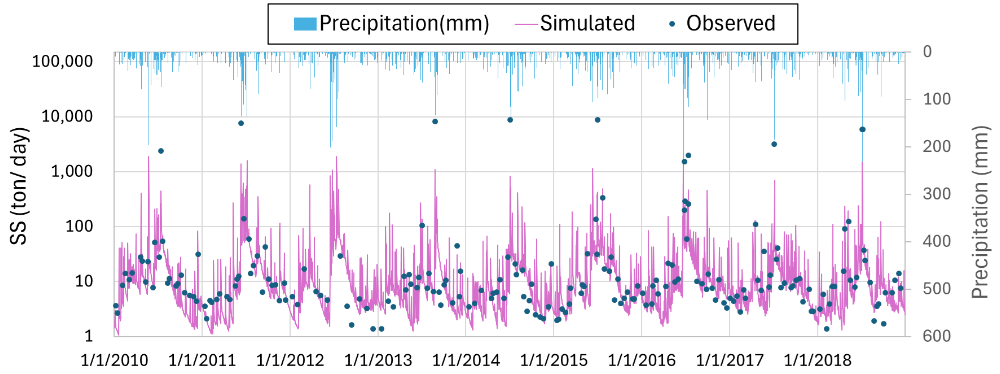
Results and discussion

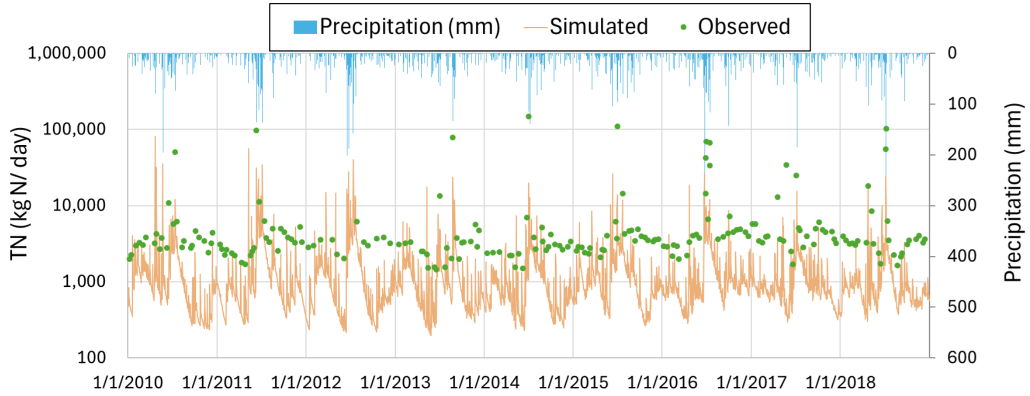
- Model performance
  - River flow, SS, and TN at the lowest point (near the sea) of the basin were evaluated using statistical variable indicators.
  - For the 2010s model,
    - ✓ Calibration period: 2014-2018
    - ✓ Validation period: 2010-2013



	River flow		SS		TN	
	Calibration	*Validation*	*Calibration*	*Validation*	*Calibration*	*Validation*
RSR	0.536	0.323	0.93	0.90	0.93	0.78
NSE	0.713	0.896	0.13	0.18	0.13	0.39
PBIAS	4.335	-8.743	85.68	83.60	79.22	66.54

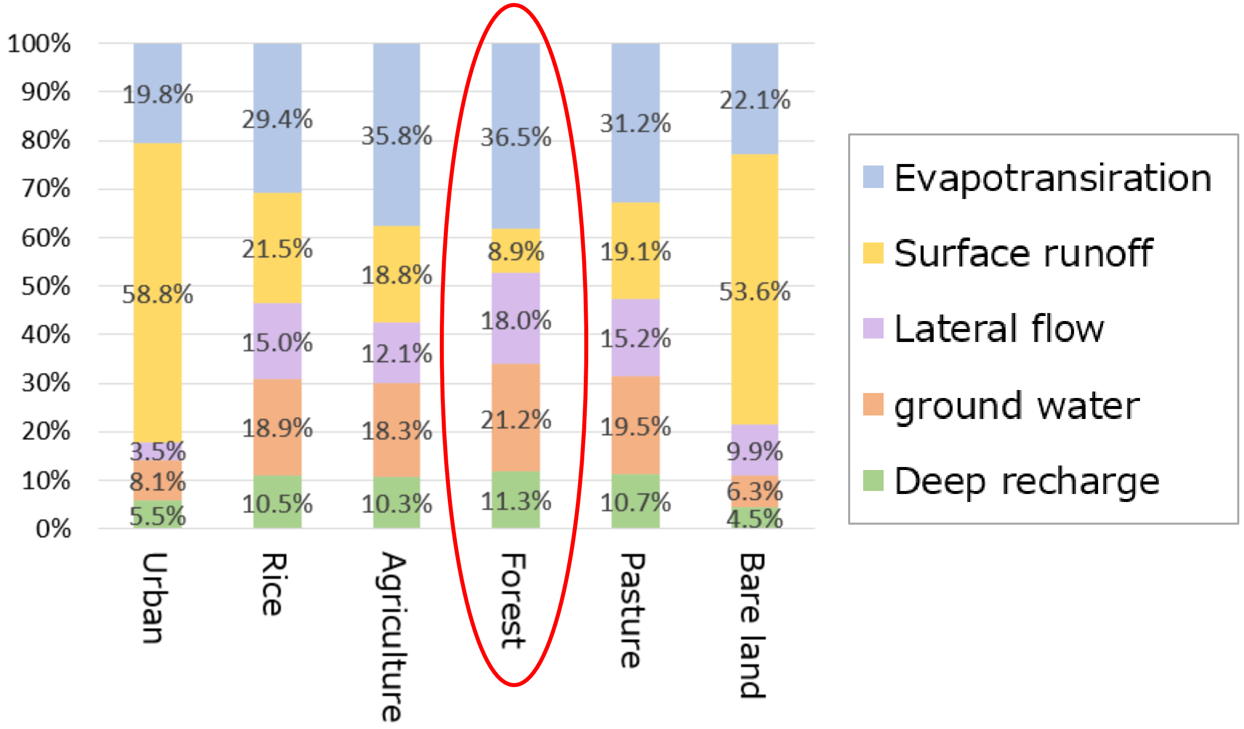




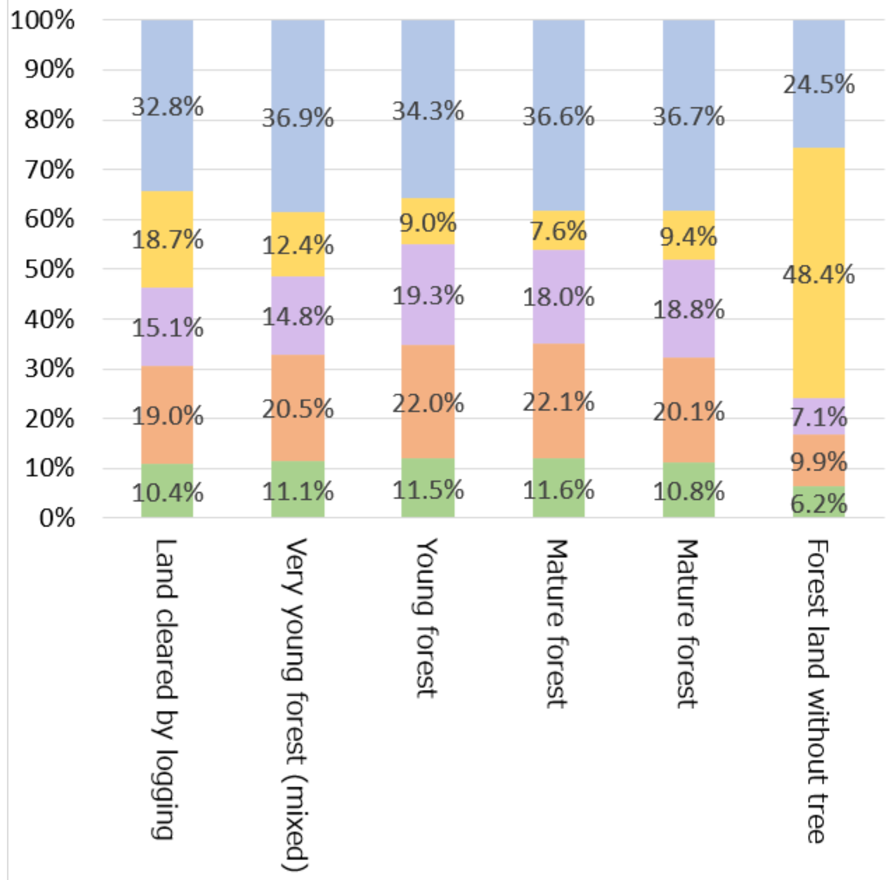


Results and discussion

➤ Water balance for each LULC



➤ Water balance for each forest type



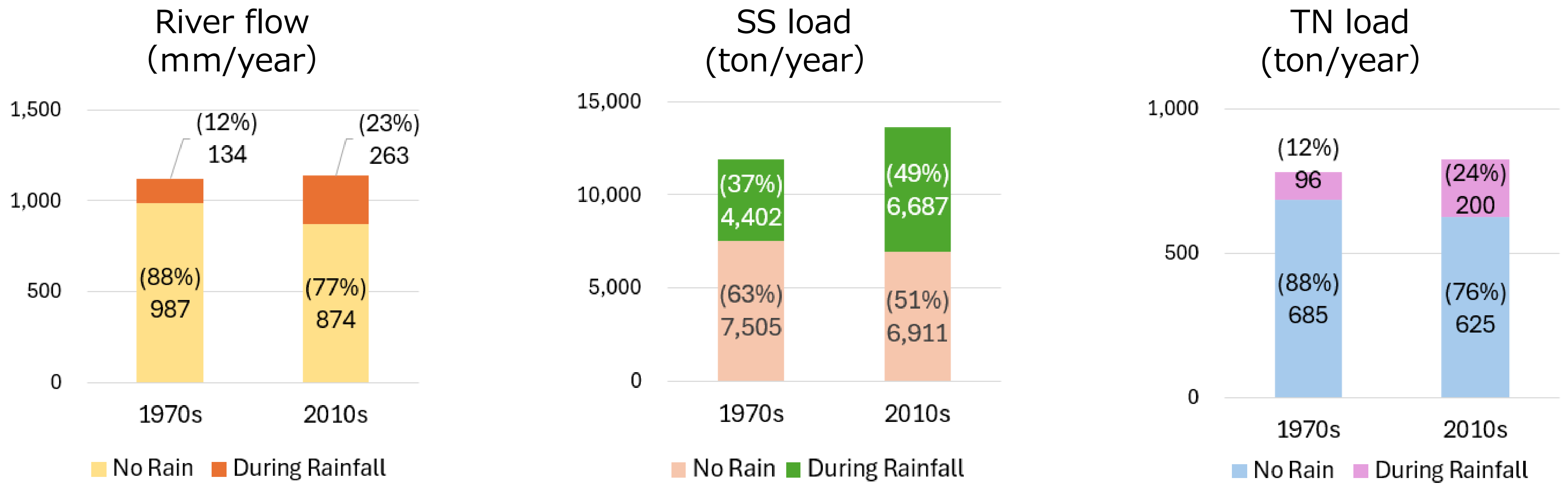
- *The water balance of forest land became adequate compared to other LULC;*
  - ✓ High evapotranspiration
  - ✓ Low surface runoff
  - ✓ High baseflow and recharge

- *The water balance for each developmental stage of forest was also set appropriately.*

Results and discussion

- Comparison of model outputs for the total annual volumes of river flow, SS, and TN between 1970s and 2010s

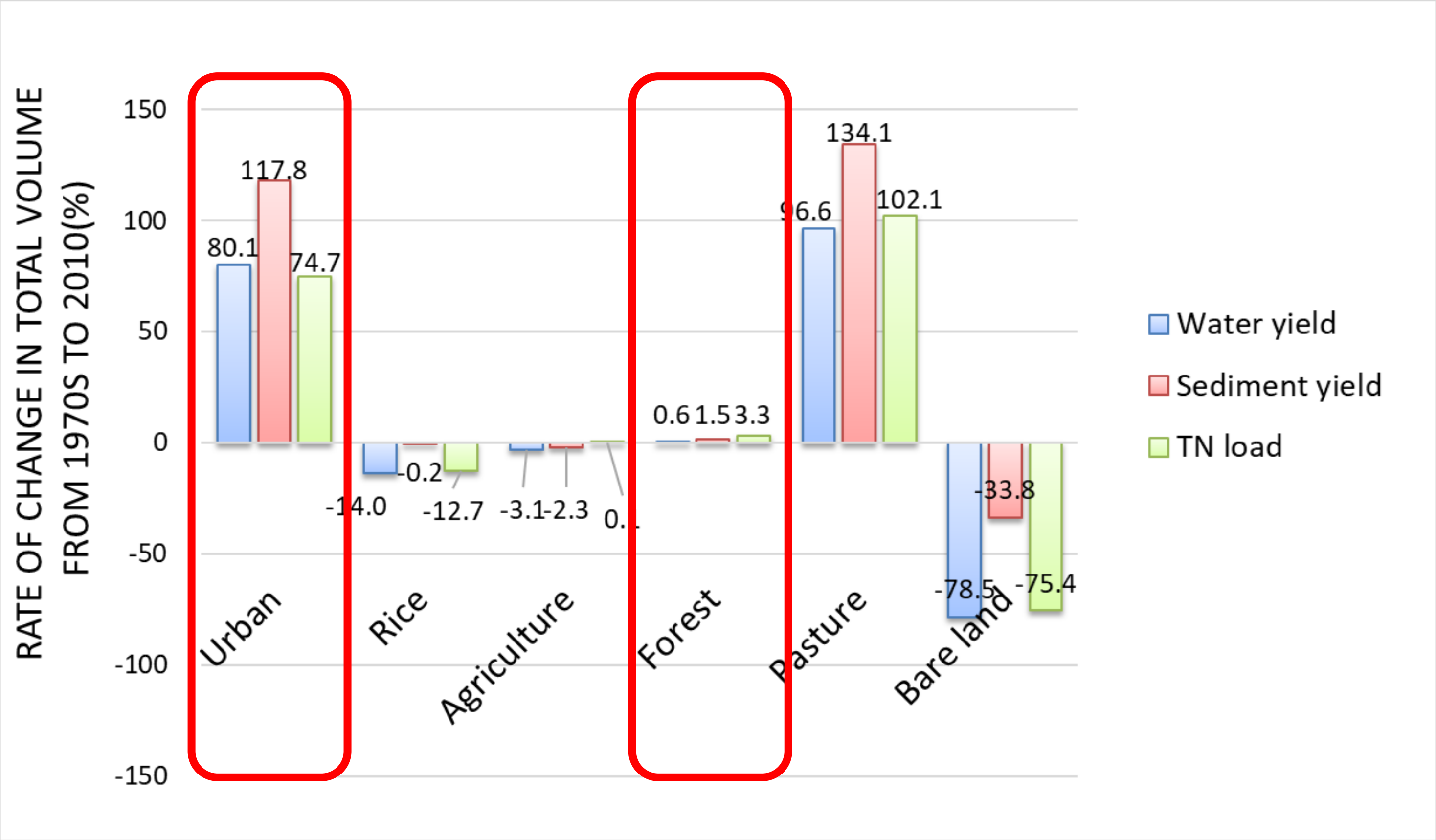
- This estimate was based on precipitation in 20182094mm).
- "During Rainfall" means the days when 74mm or more of rain (1-year return period) was observed.



- The results showed that the total volumes in the 2010s were slightly higher than that in the 1970s.
- Could this be caused by urbanization downstream or changes in forest cover upstream??

Results and discussion

➢ The rate of change in total annual volume in each LULC between 1970s and 2010s



- *The increase in total volume in urban areas is remarkable while that in forest land remained almost unchanged.*
- *The change rates of pasture and bare land are also large; however, the impact of those LULCs might be small as those areas within a basin is not large.*

Summary and future work

- In this study, the SWAT model was used to evaluate the impact of forest cover changes on hydrologic responses in the Kikuchi River basin.

- As a result, unlike the expansion of urban areas in the downstream basin, which is one of the major influencing factors, the change in forest cover in the upstream basin over a 40-year period did not have a significant effect on the amount of water and materials transported from the study basin to the Ariake Sea.

- This implies that the presence of forests, regardless of their stage of development, contributes to controlling water and materials transport from the basin, but that replacing forest land with other land uses can have large impact on the amount of materials that flow into the ocean.

Summary and future work

- In terms of the SWAT applicability to the mountain forested watershed;

  - Adjusting the forest-related parameters on the database can improve the forest representation in the model and enhance the applicability of forested watershed simulation; the method applied in this study may serve as a guide for similar studies.

  - For the future study, It is recommended that observational data be collected that will enable the assessment of the impacts of forest management such as thinning and harvesting.

Thank you for your attention.