EVALUATION OF THE IMPACT OF FOREST COVER CHANGE IN THE UPPER KIKUCHI RIVER BASIN ON SEDIMENT AND NUTRIENT TRANSPORT TO THE ARIAKE SEA, JAPAN

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Motivation

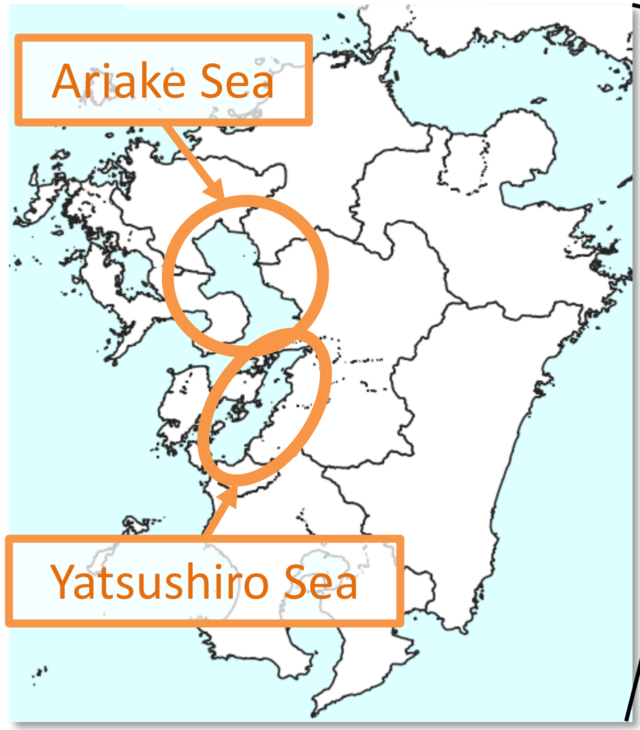
- Forests are expected to be one of the "nature-based solutions (NbS)" for various social issues through their ecosystem services, and there is a growing need for their quantitative evaluation.
- SWAT model is an effective tool for integrated watershed modeling, however, in order to apply it to mountainous forested areas, it is necessary to improve the representation of forest ecosystems in the model.

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.

Kyushu region



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 2 models where LULCs of different time points (2010s, 1970s) is applied to each model.
  - Apply fitted parameter values for 2010s model to 1970s model.
  - Enhance the representation of Japanese forest ecosystems in a SWAT model.

1) Model development

Weather (2010s)	DEM (2010s)	LULC (1970s/ 2010s)	Soil (2010s)

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2) Input & Parameter setting

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3) Calibration & Validation

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4) Simulation

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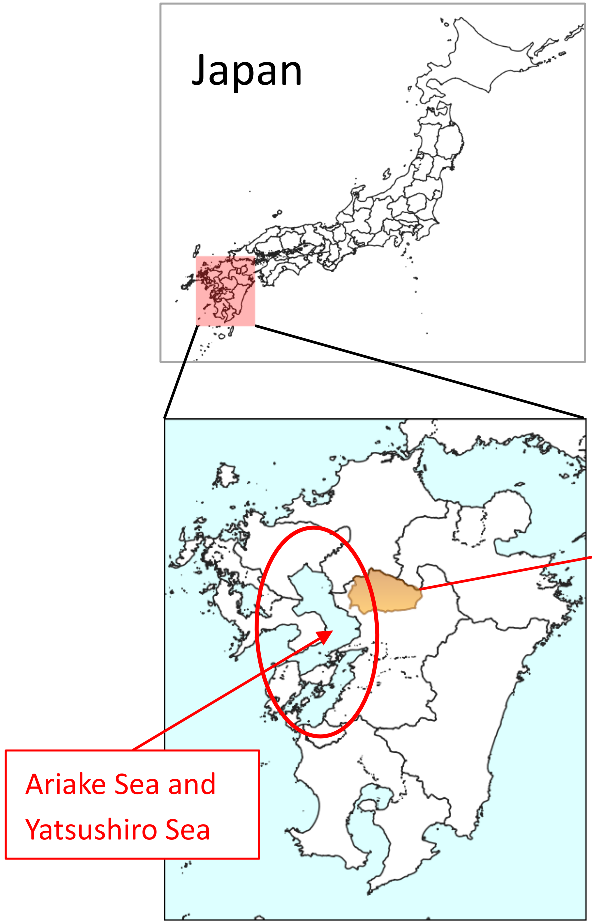
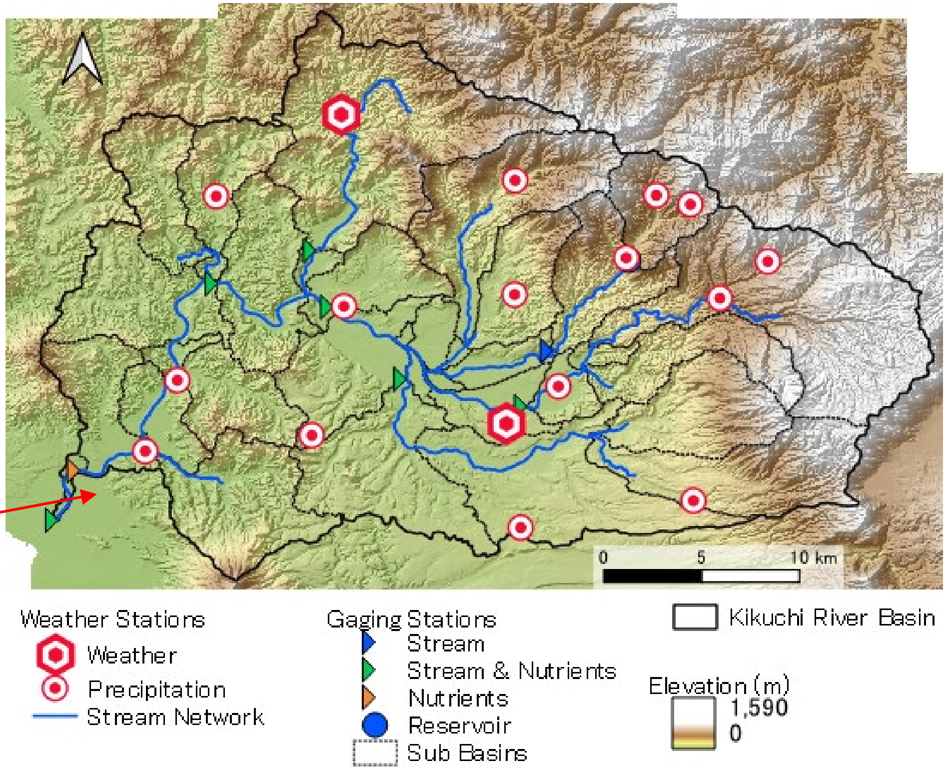
5) Analysis & Evaluation

Study area description

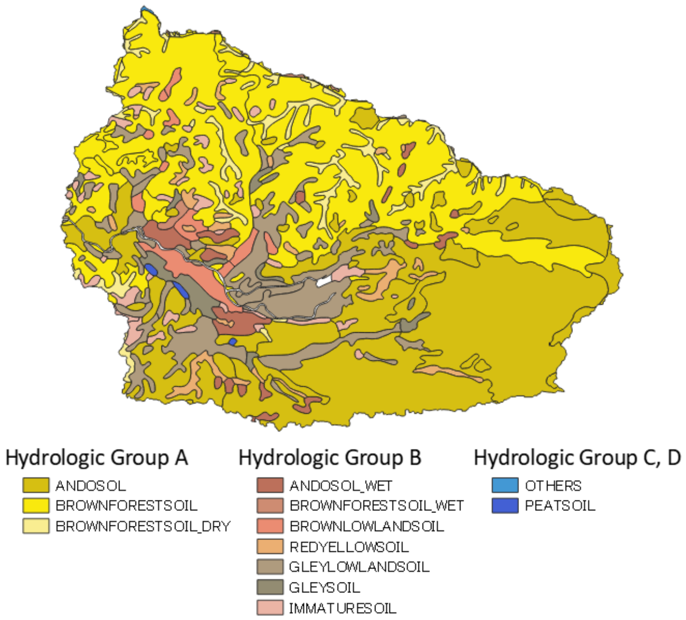


Kyusyu Region

■ 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%



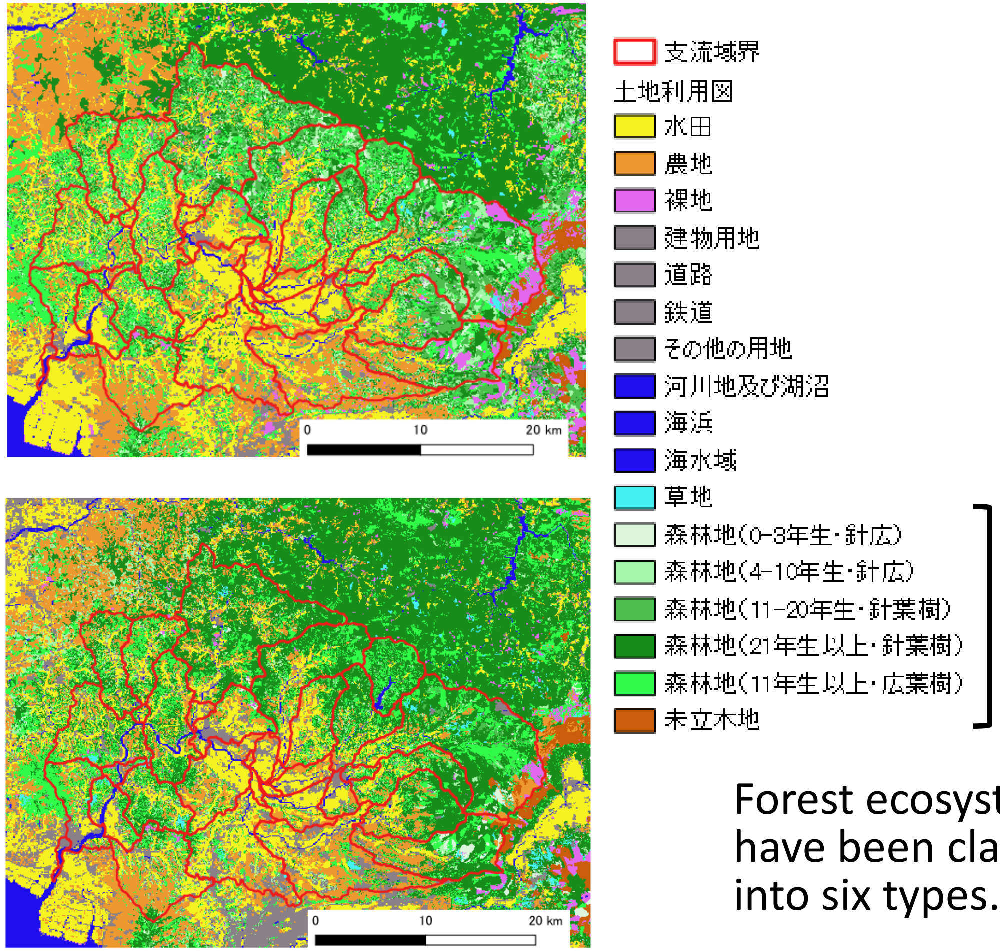
Dominant soil type are ANDSOL, BROWN FOREST SOIL, which are categorized as hydrologic A, covers more than half area of the basin

Study area description

■ LULC

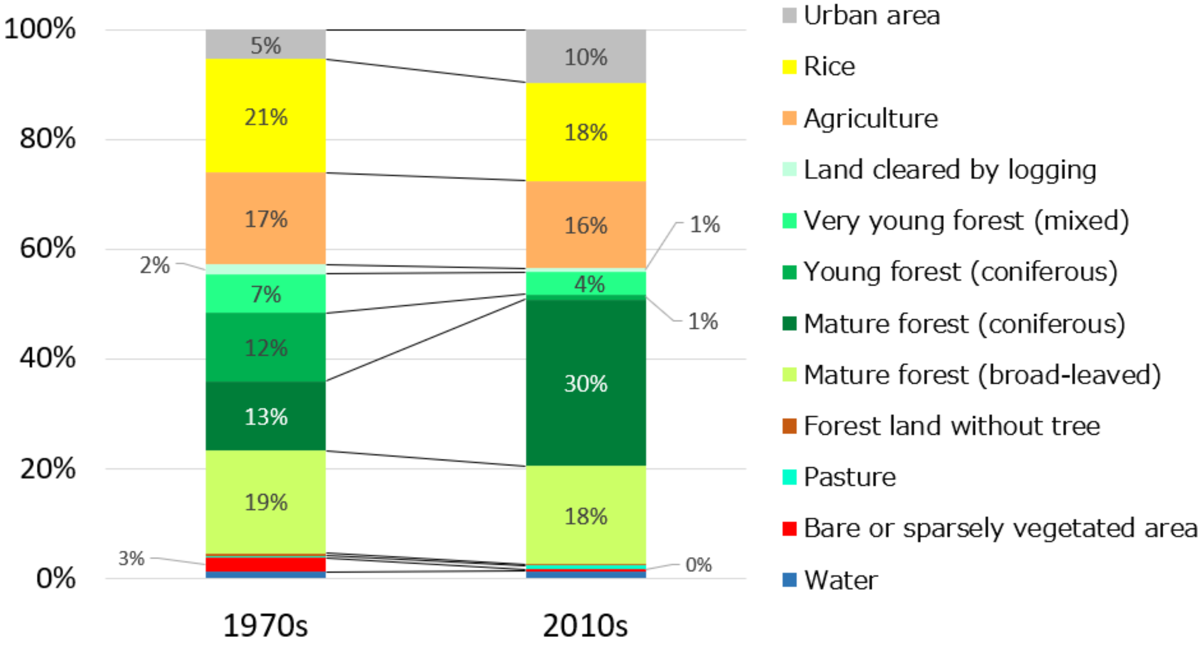
1970s

2010s



Forest ecosystems have been classified into six types.

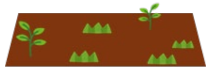
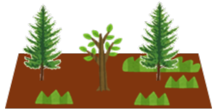
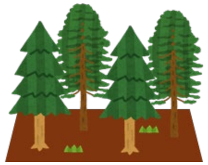
LULC Change from 1970s to 2010s



- 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 tree
Age		0-3	4-10	11-20	21<	11<	-
Hydrological behavior	Evapo-transpiration						
	Surface/Sediment runoff						
	Soil infiltration /Percolation						
	Nitrogen transport to river						

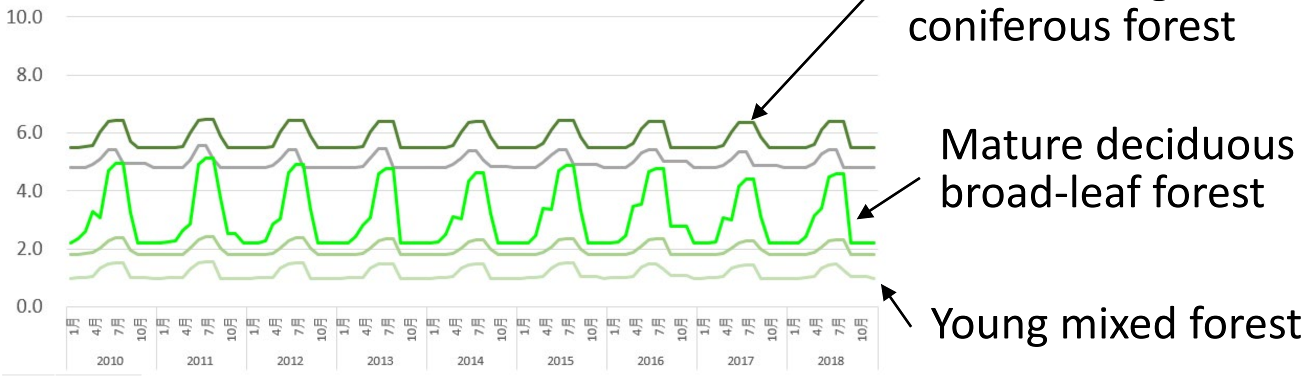
Adoption of forest-related parameters in SWAT

➢ 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.

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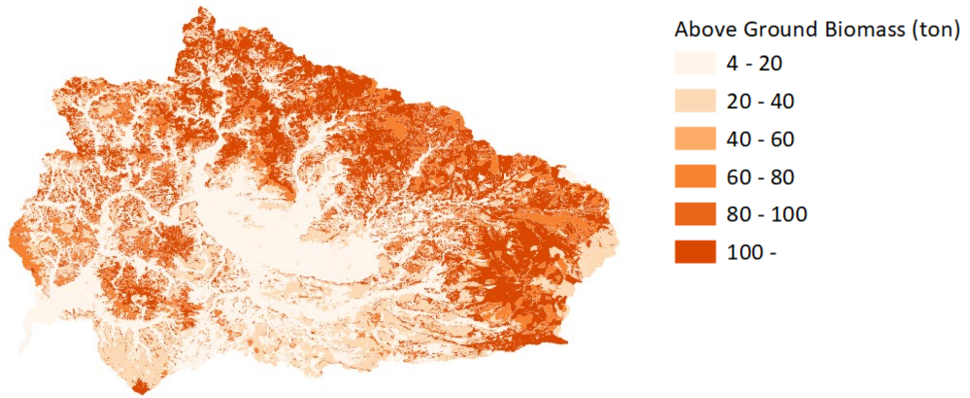
Adoption of forest-related parameters in SWAT

2) Biomass

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

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

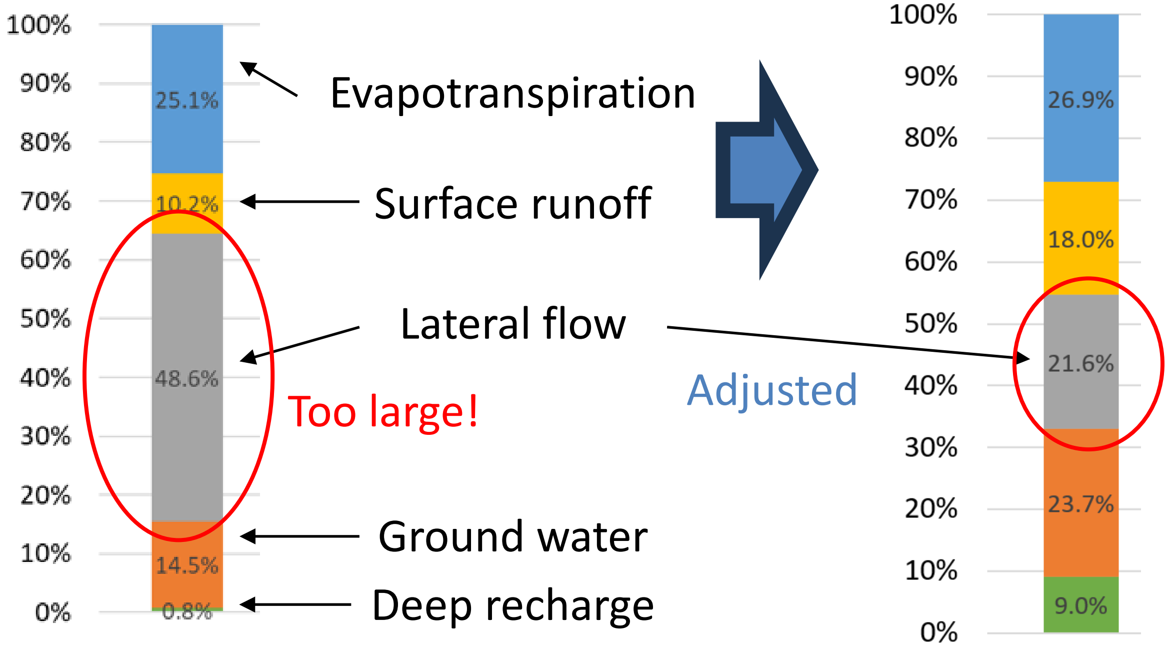
- Adopted biomass with reference to High-Resolution Land-Use and Land-Cover Map Products (JAXA).



- For young to mature forests, LAI 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* was adjusted to obtain adequate lateral flow rate within the water balance.



Adoption of forest-related parameters in SWAT

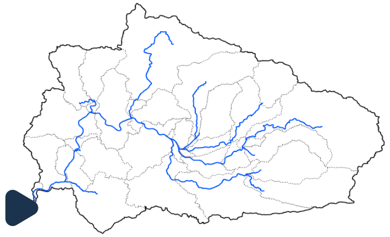
- Other fitted parameters

Table	Parameters	Defaut value	Fitted value	Definition
GW	ALPHA_BF	0.048[1/days]	0.562	Baseflow alpha factor.
	GWQMN	1000[mm]	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[mm]	305	Threshold depth of water in the shallow aquifer for "revap" to
	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.
	SOL_K2	-999 [mm/hr](0-200)	31-37	Saturated hydraulic conductivity.
	SOL_AWC1	0.032－0.35[mm/hr]	0.22-0.50	Available water capacity of the soil layer.
	SOL_AWC2		0.45	Available water capacity of the soil layer.
	SOL_BD1		0.60-0.81	Moist bulk density.
	SOL_BD2		0.85-0.91	Moist bulk density.
MGT	CN2		44 - 82	SCS runoff curve number for moisture condition 2
HRU	SLSUBBSN	9-91[mm]	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[mm]	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	

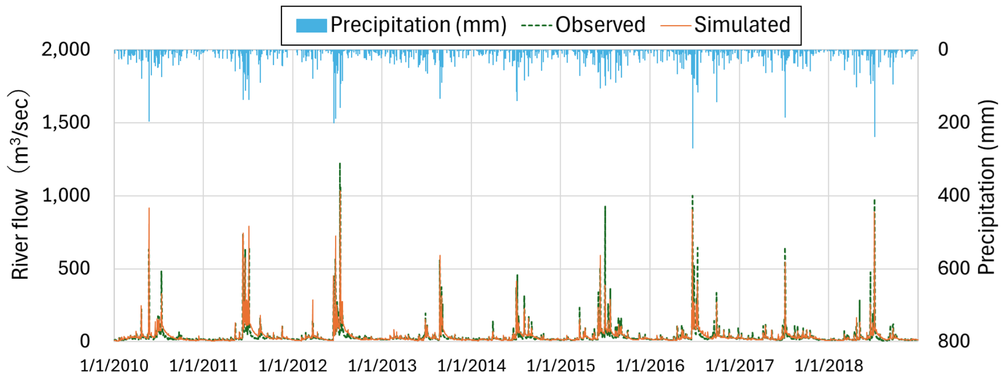
Results and discussion

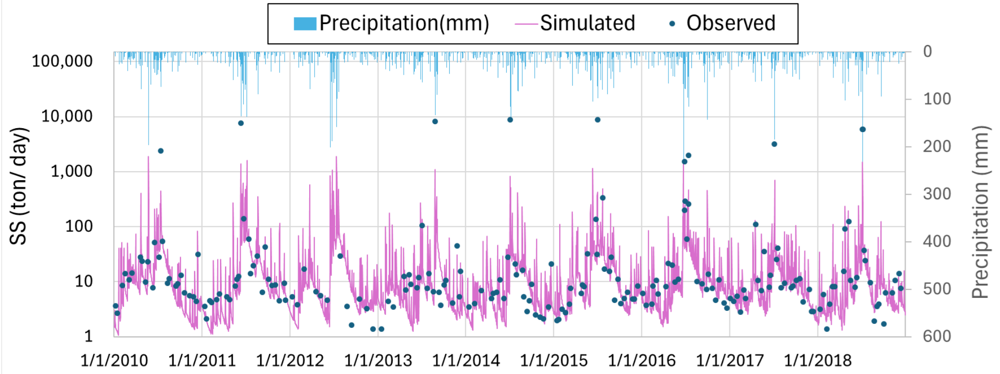
➢ Model performance

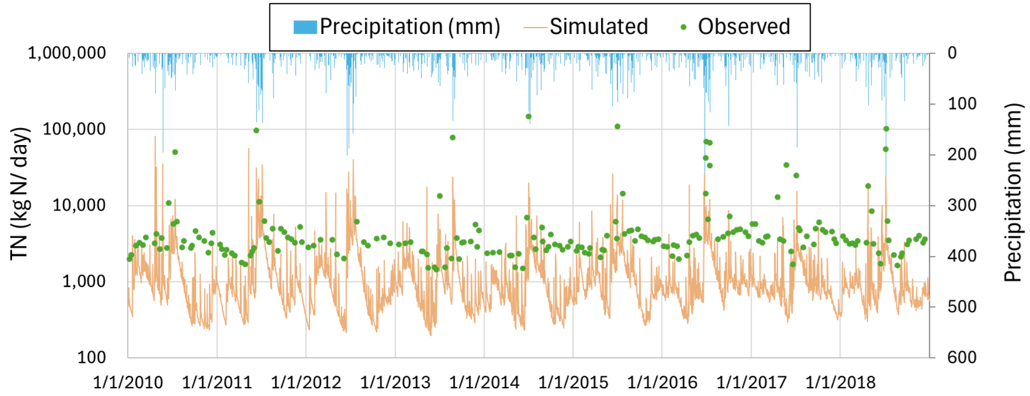
- River flow, SS, and TN at the lowest point (near the sea) of the basin were evaluated using statistical variable indicators.
- For the 2010s model,
  - ✓ Calibration period: 2014-2018
  - ✓ Validation period: 2010-2013



	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

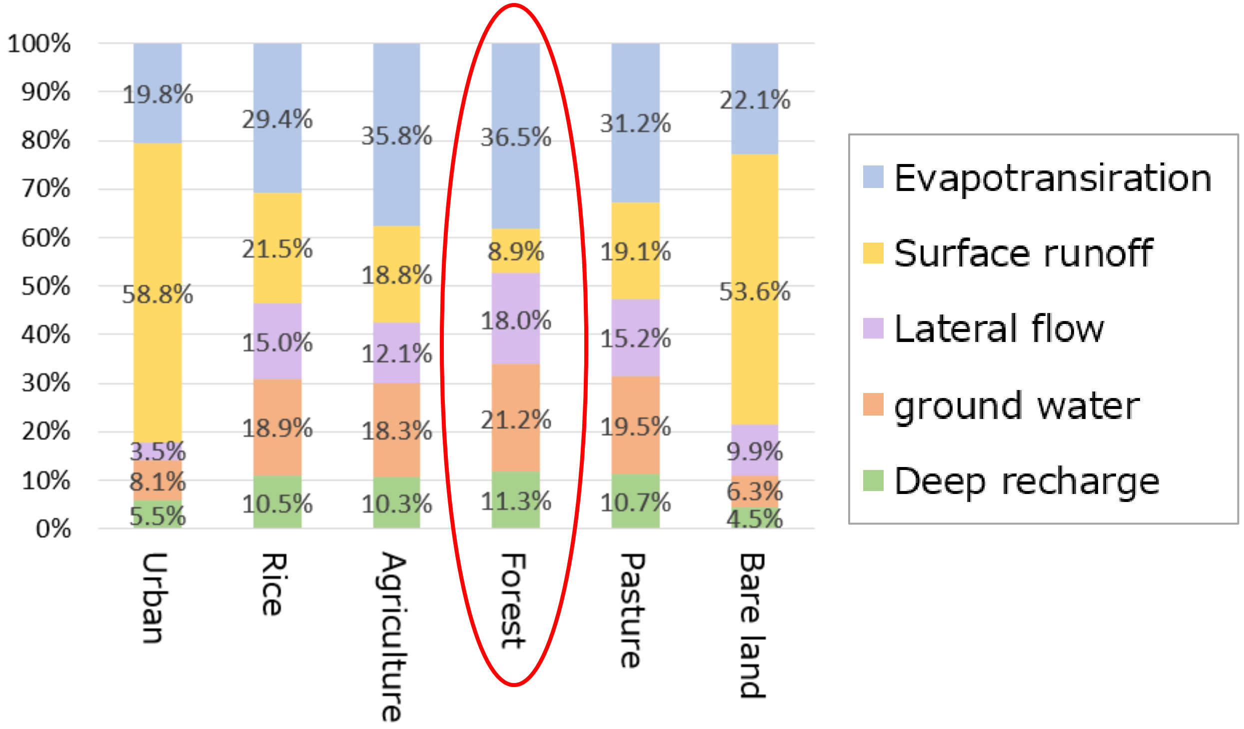




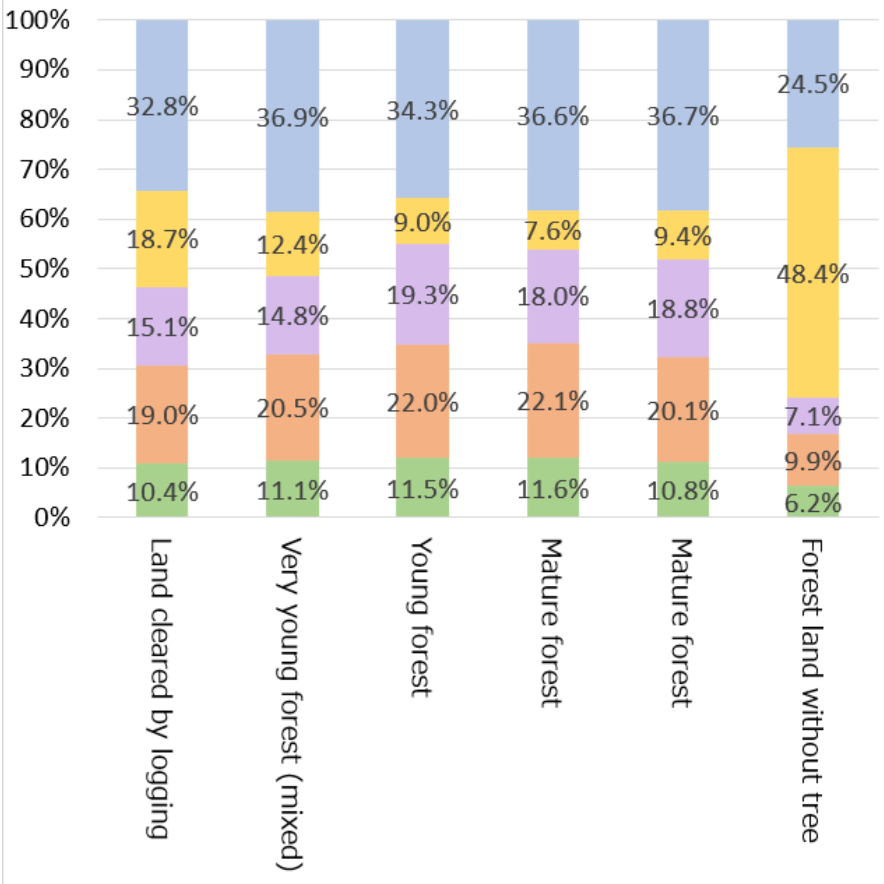


Results and discussion

➢ Water balance for each LULC



➢ Water balance for each forest type



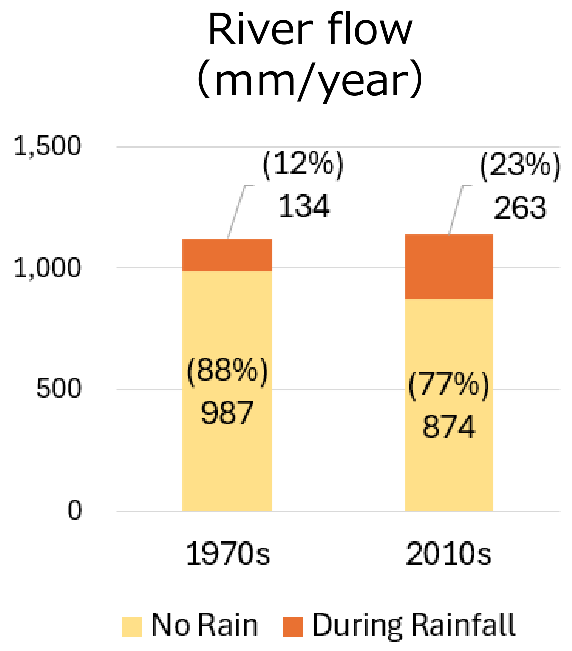
- *The water balance of forest land became adequate compared to other LULC;*
  - ✓ High evapotranspiration
  - ✓ Low surface runoff
  - ✓ High baseflow and recharge

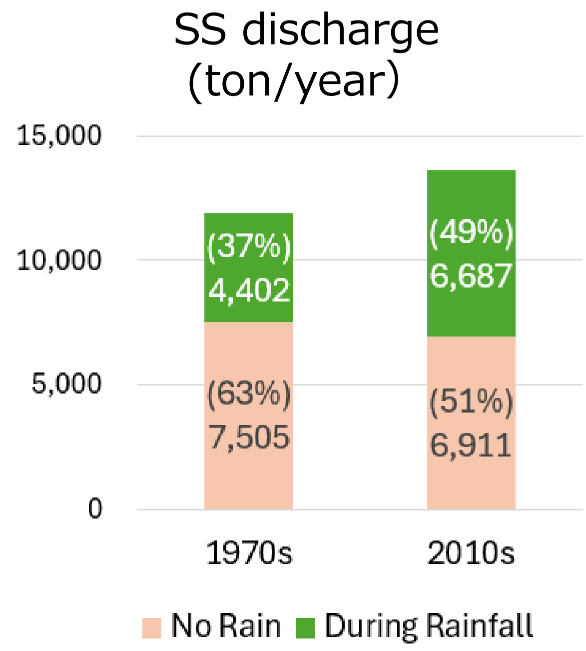
- *The water balance for each developmental stage of forest was also set appropriately.*

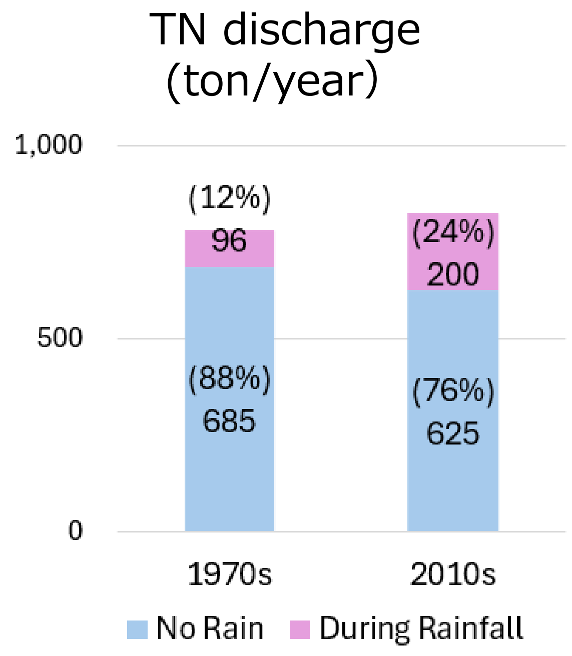
Results and discussion

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

* Precipitation in 2018 (2094mm) was applied for this estimation
* "During Rainfall" is the days when 74mm or more of rain (1-year return period) was observed.





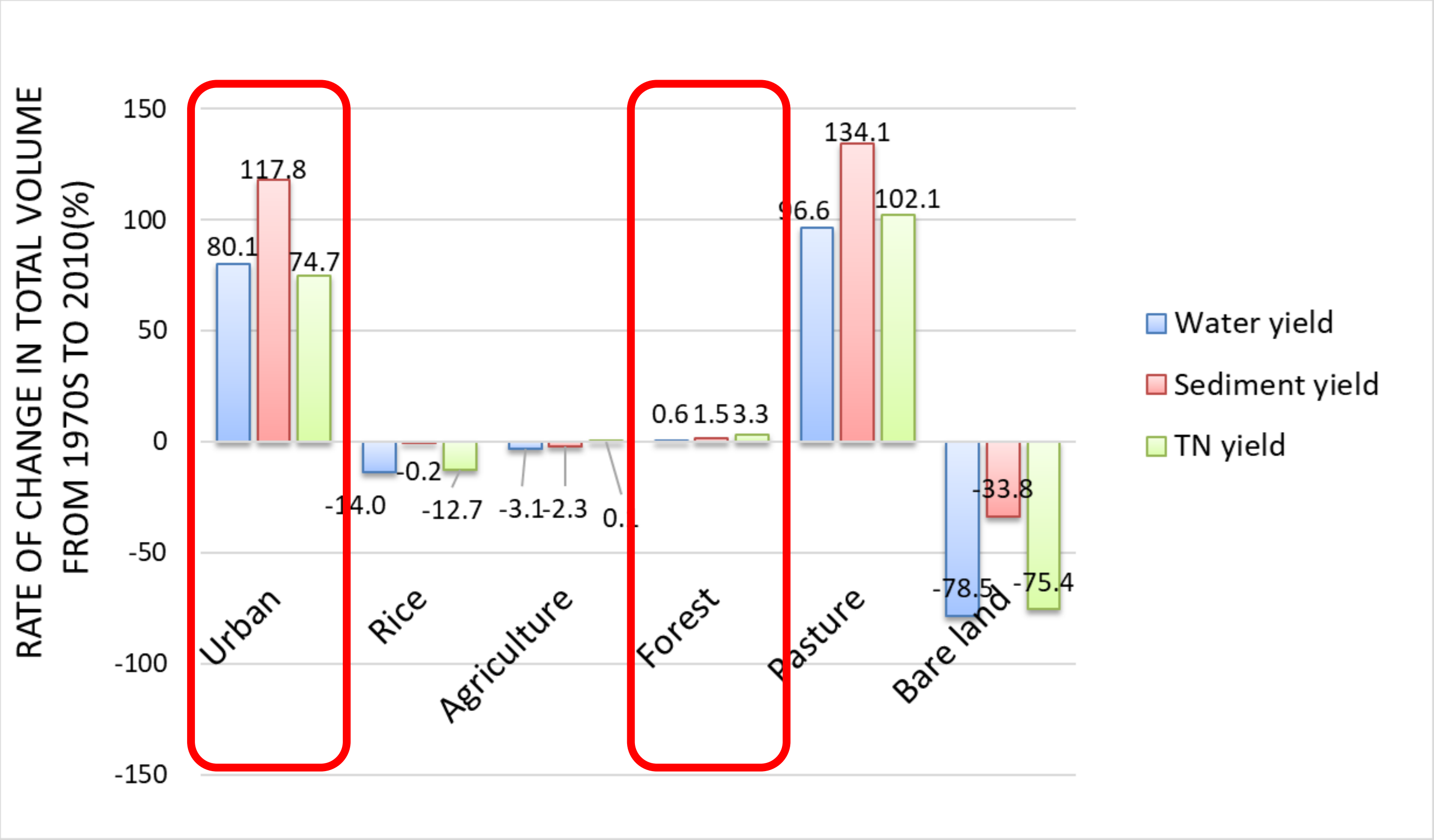


➢ The results showed that the total volumes in the 2010s were slightly higher than in the 1970s.

➢ Could this be caused by urbanization downstream or changes in forest cover upstream??

Results and discussion

- The rate of change in total annual volume for each LULC source.



- Increase in volume from urban area is significant while that from forest stay almost the same level.

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.
- The results showed that urban areas within the basin have a certain impact on the amount of water, sediment, and nitrogen transported to the sea.
- The change in forest cover from relatively young to mature forest over a 40-year period did not significantly affect the amount of water or materials flowing out of the study basin into the ocean.
- This implies that LULC change is one factor that has significant impacts on the environment of the Ariake sea, if that happens especially in mountainous area.

Summary and future work

- ➢ In terms of the SWAT applicability to the mountainous forest watershed;
  - By updating the database and setting parameters, the representation of forests in the model was enhanced, which will serve as a guide for similar studies.
  - For the future study, It is recommended to obtain more monitoring data to improve the representability of the model.

Thank you for listening !