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Assessment of Water Resources and Hydrological Conditions by Using the SWAT Model in the Stung Sen River Basin, Cambodia

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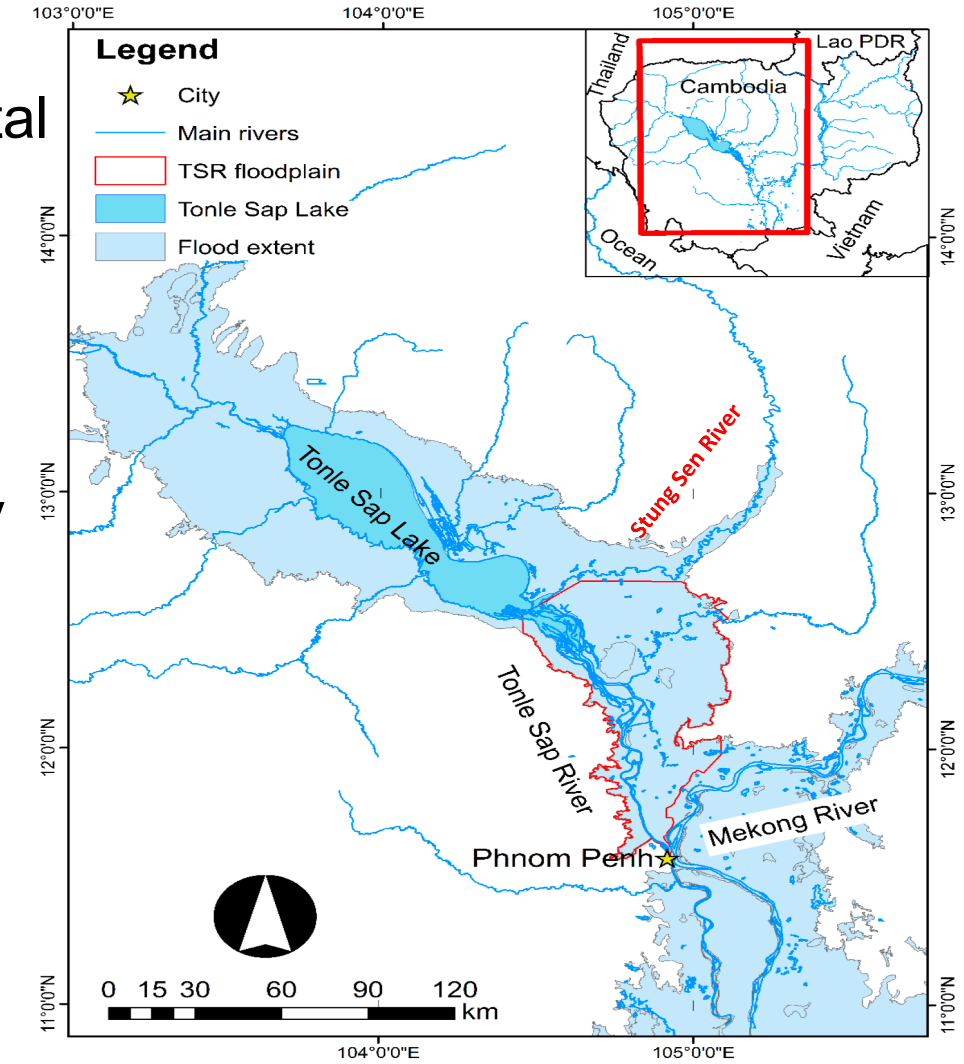
Background

- Tonle Sap Lake is a main source for social-environmental development in Cambodia

- Irrigation schemes have dramatically increased due to the increase in agricultural land use (MoWRAM & ADB, 2019)

- Previous studies found that changing runoff significantly impacted some sub-basins (Oeurng et al., 2019)

- The Stung Sen River has quickly developed rehabilitation and existing small- and medium-scale irrigation systems along the river basin (MoWRAM & ADB, 2014)

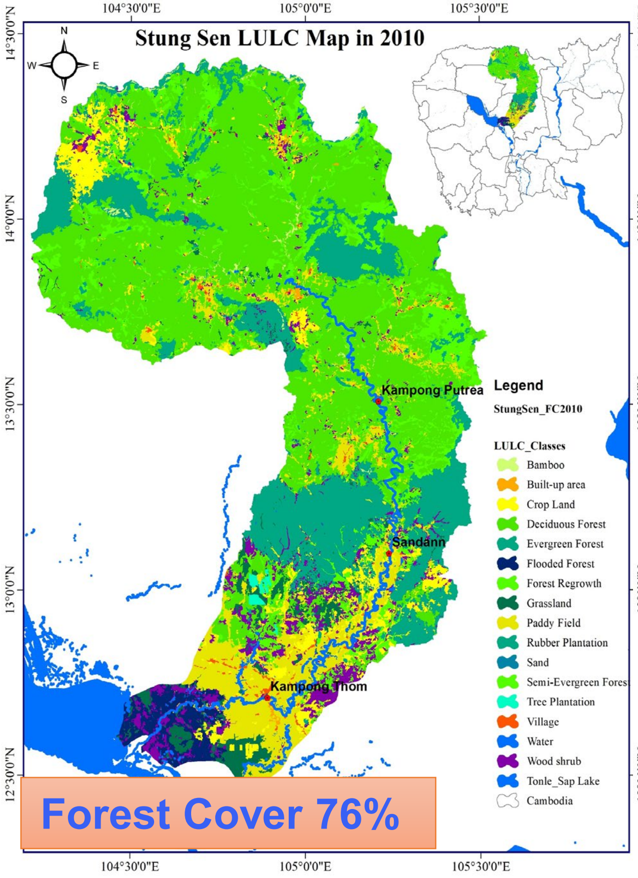


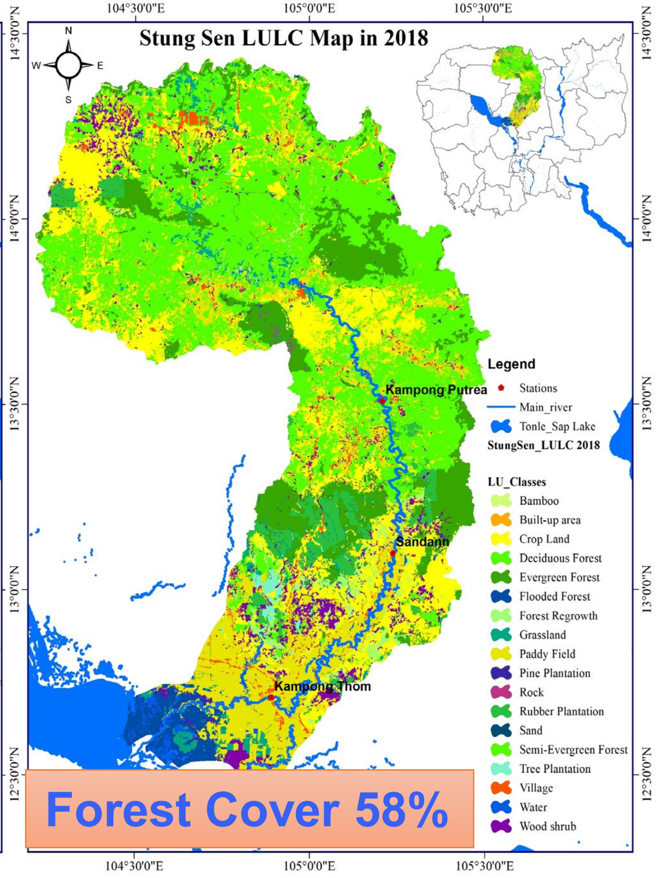
Tonle Sap Lake and its tributaries

Research Objectives

- To assess the impact of land use change on streamflow in the Stung Sen River
- To evaluate the hydrological processes of the watershed

❖ Study area





LULC map in **Sen River Basin (MOE)**

- Stung Sen River was selected in this research
- Total area: **16,344 km^2**
- Annual rainfall: **1,600 mm**
- Average temperature: **23 °C**

The average discharge observed at Kampong Thom Station
- 2007-2012 = **8,568 million m3** (before irrigation scheme)
- 2013-2021= **7,943 million m3** (after irrigation scheme)

Materials and Methods

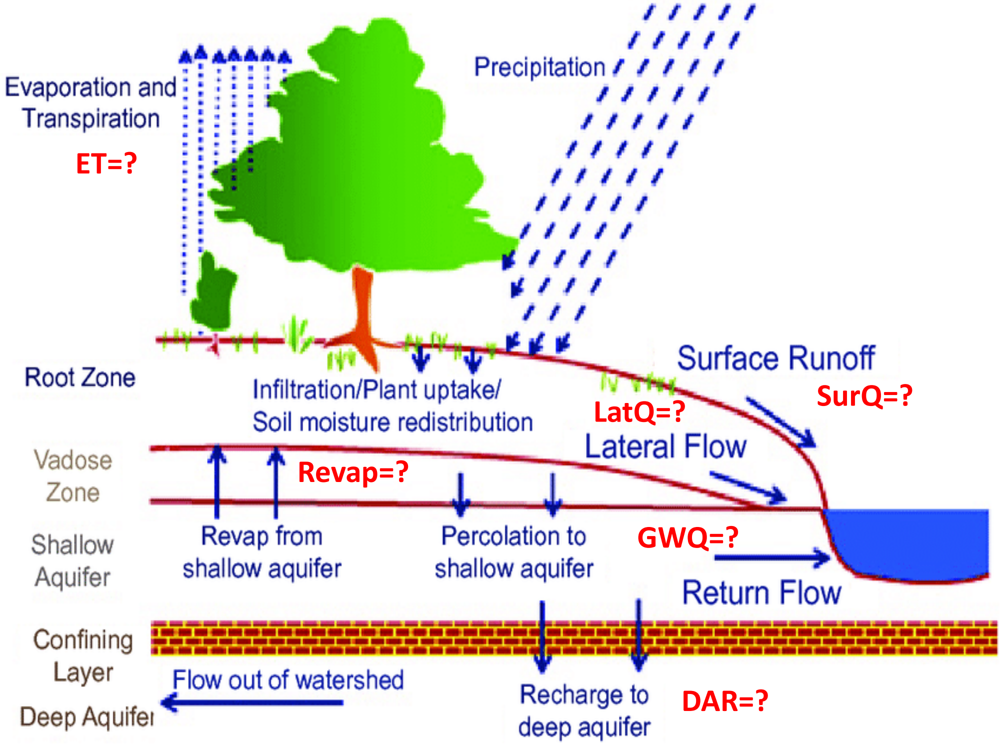
- **Soil and Water Assessment Tool (SWAT)** model is a widely used hydrological model and developed by the United States Department of Agriculture-Agricultural Research Service (USDA-ARS)

- SWAT model was applied **for hydrological analysis**, **water balance,** and **discharge processes** with land use management

Water balance equation in SWAT

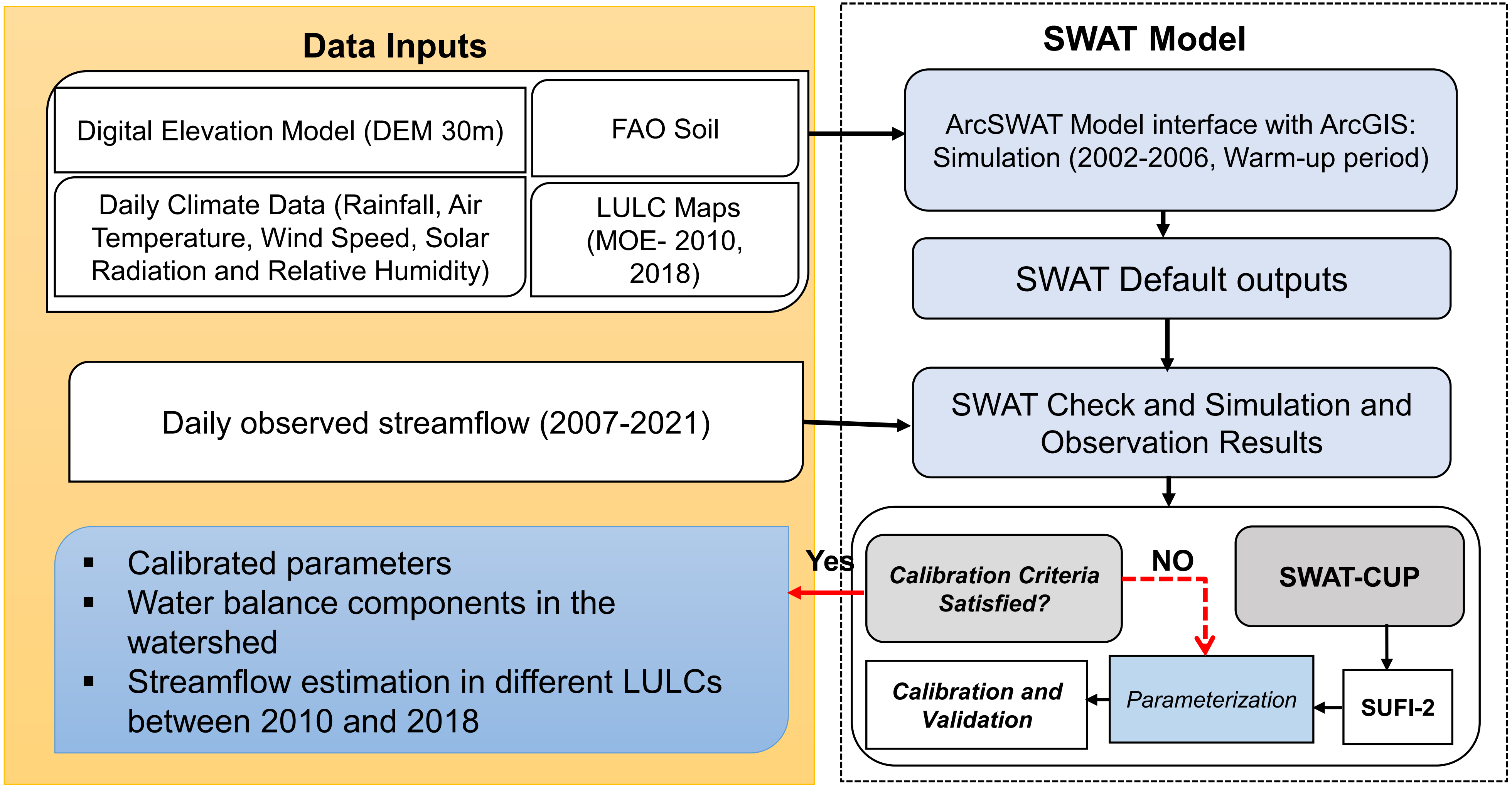
$$SW_t = SW_o + \sum_{i=1}^{n}(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw})$$

SWt : final soil water content
SWo : initial soil water content
Rday : amount of precipitation
Qsurf : amount of surface runoff
Ea : amount of evapo-transpiration
Wseep : amount of water entering unsaturated zone
Qgw : amount of return flow



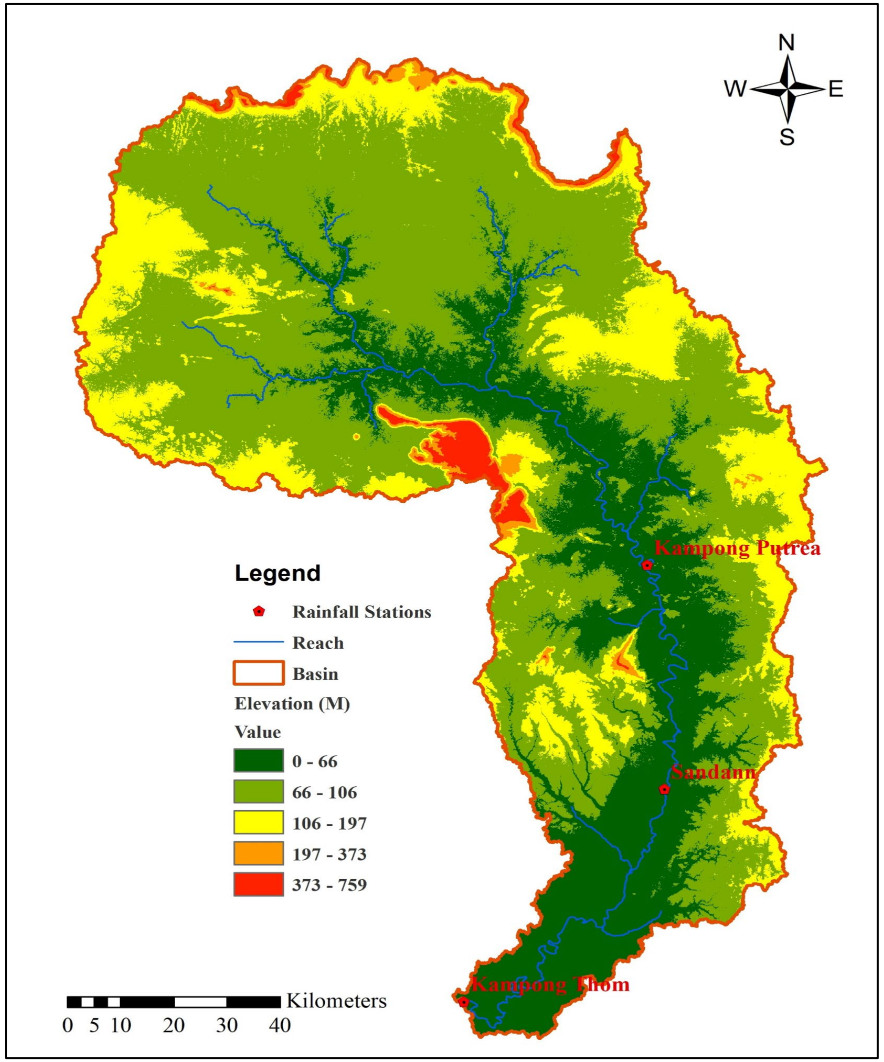
Hydrologic processes simulated in SWAT

Materials and Methods (cont.)



Working flow chart for assessing streamflow using SWAT model

SWAT Model Setup



Elevation range from 0-759m

- Elevation: **759 m**
- Number of Sub-basins: **27**
- Number of HRUs: **523**
- SWAT is covered **14,465 km2** (~88%) of total area **16,344 km²** with outlet Kampong Thom Station
- Soil type: Ferric Acrisols (44%)
  Gleyic Acrisols (32%)
  Orthic Acrisols (14%)
  Eutric Gleysol (10%)

- Deciduous-forests **(13%),** Evergreen and Semi-Evergreen **(8%)** were decreased
- Cropland **(14%),** and paddy fields **(5%)** were increased

Results and Key Findings

Table 1. Parameters used for the final calibration and validation

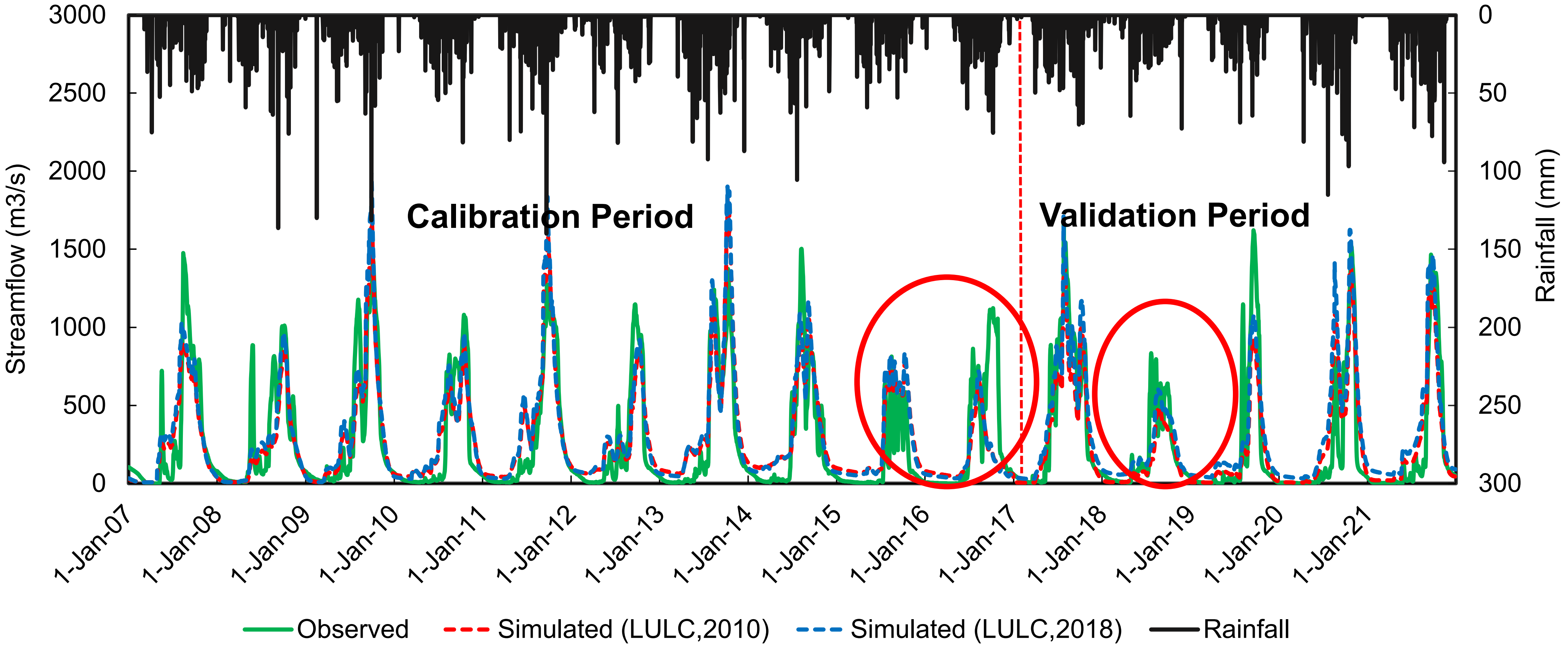
Parameters	Ranging	Extension	Description	Process	Initial Ranges		Fitted Value
					Min	Max	
1:V__ALPHA_BF	**1**	**.gw**	**Baseflow alpha factor (1/days)**	**Groundwater**	**0**	**1**	**0.20**
2:V__GW_DELAY	**2**	**.gw**	**Groundwater delay time (days)**	**Groundwater**	**0**	**450**	**288**
3:R__CN2	3	.mgt	Initial SCS curve number II value	Runoff	-0.2	0.2	0.08
4:R__SOL_AWC (..)	4	.sol	Available water capacity	Soil	-0.5	0.5	0.70
5:V__ESCO	5	.hru	Soil evaporation compensation factor	Evaporation	0	1	0.40
6:V__GWQMN	6	.gw	Threshold depth of water in the shallow aquifer	Groundwater	0	5000	3886
7:V__CH_K2	7	.rte	Effective hydraulic conductivity of channel	Channel	0	500	230

ALPHA_BF and GW_DELAY were the most sensitive parameters, forest cover **(~80%)** in the SWAT application, so functions related to water, such as high groundwater recharge and low runoff

Table 2. Model performance evaluation for daily streamflow

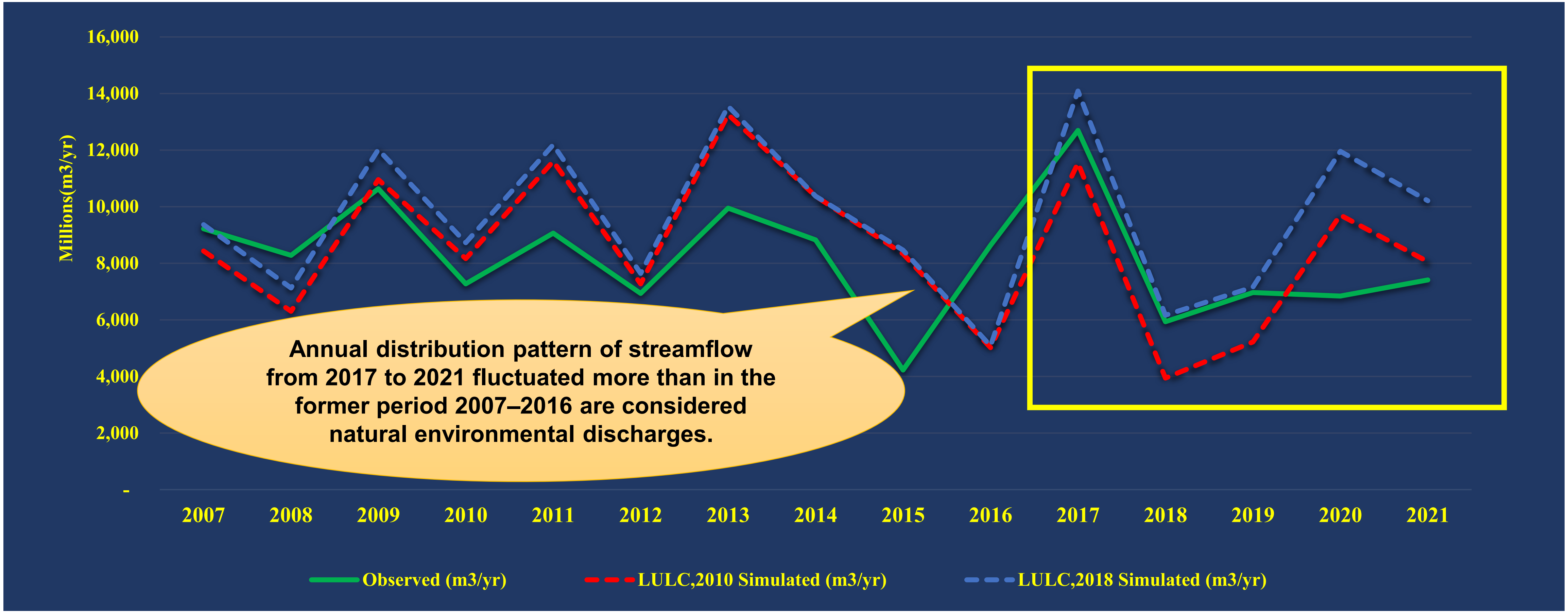
Statistics	LULC2010				LULC2018	
	Calibration (2007-2016)		Validation (2017-2021)		Calibration (2007-2021)	
	Observed	Simulated	Observed	Simulated	Observed	Simulated
Mean (m3)	263	284	253	244	260	304
Maximum (m3/s)	1503	1849	1665	1423	1665	1987
Minimum (m3/s)	0	7	0	4	0	7
Standard Deviation (m3/s)	358	312	394	325	370	345
	Performance Evaluation		Performance Evaluation		Performance Evaluation	
Nash–Sutcliffe Efficiency **(NSE)**	**0.70**	Very Good	**0.78**	Very Good	**0.71**	Very Good
Coefficient of Determination **(R2)**	**0.70**	Very Good	**0.77**	Very Good	**0.73**	Very Good
Percent bias **(PBIAS)**	-8	Very Good	3.5	Very Good	-17	Very Good

The results showed that very good performance of the model with **NSE, R2 over 0.7**, and PBIAS **ranging from 4% to 17% for the calibration and validation**.



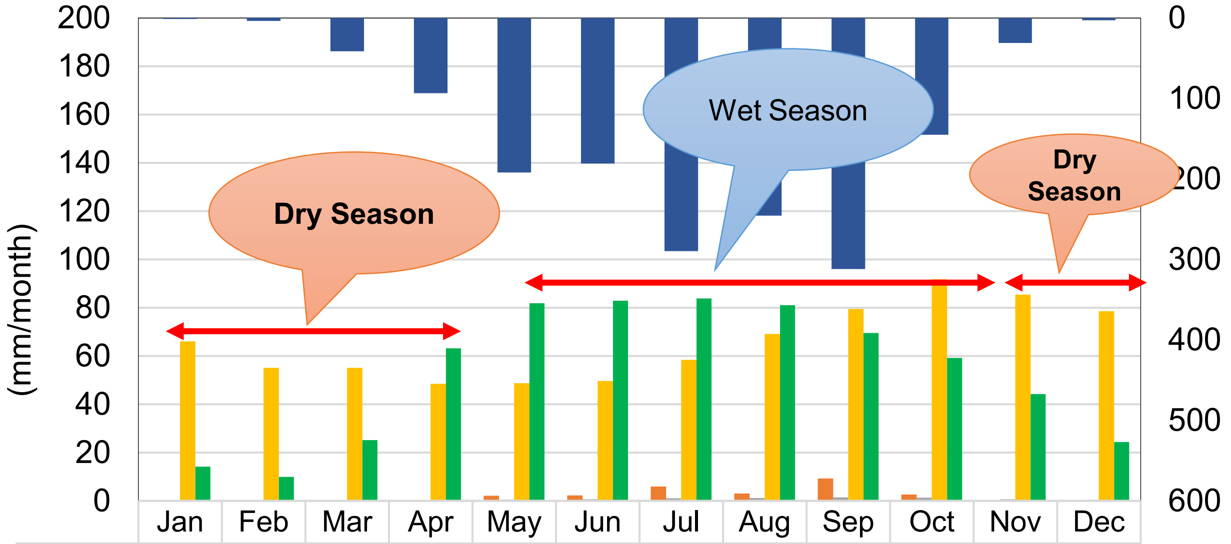
Observation and simulation daily streamflow with difference land use (2007-2021)

The simulated discharges corresponded well with observed flows; however, certain peak flow estimations in several years of **streamflow fluctuation between 2015, 2016 and 2018.**



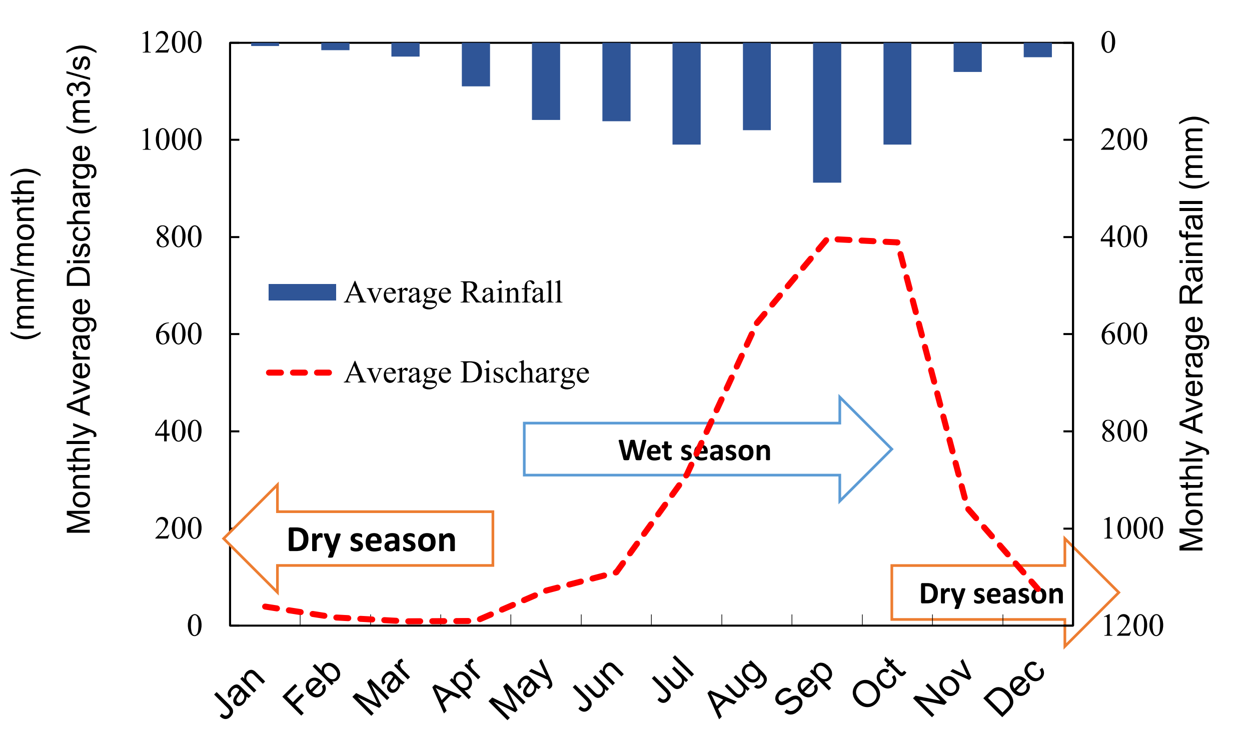
Annual Simulation and Observation Streamflow (2007-2021)

The average discharge is **8,193 million m3/year** at Kampong Thom Station. Simulation results streamflow of land-use 2010 on average was **8,545 million m3**, while simulation results streamflow of land-use 2018 was **9,609 million m3** of the total runoff volume that was higher than **1,064 million m3** in the same period from 2007-2021.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SURQ	0.0	0.0	0.1	0.3	2.2	2.3	6.0	3.1	9.4	2.7	0.0	0.0
LATQ	0.3	0.2	0.2	0.2	0.5	0.7	1.1	1.2	1.5	1.4	0.7	0.4
GWQ	66.1	55.1	55.1	48.5	48.7	49.8	58.4	69.1	79.5	91.8	85.4	78.6
ET	14.3	10.1	25.2	63.2	81.9	82.9	83.8	81.1	69.6	59.3	44.3	24.4
PCP	1.3	3.6	41.4	93.5	191.8	181.0	289.8	245.4	311.9	145.2	31.2	3.1

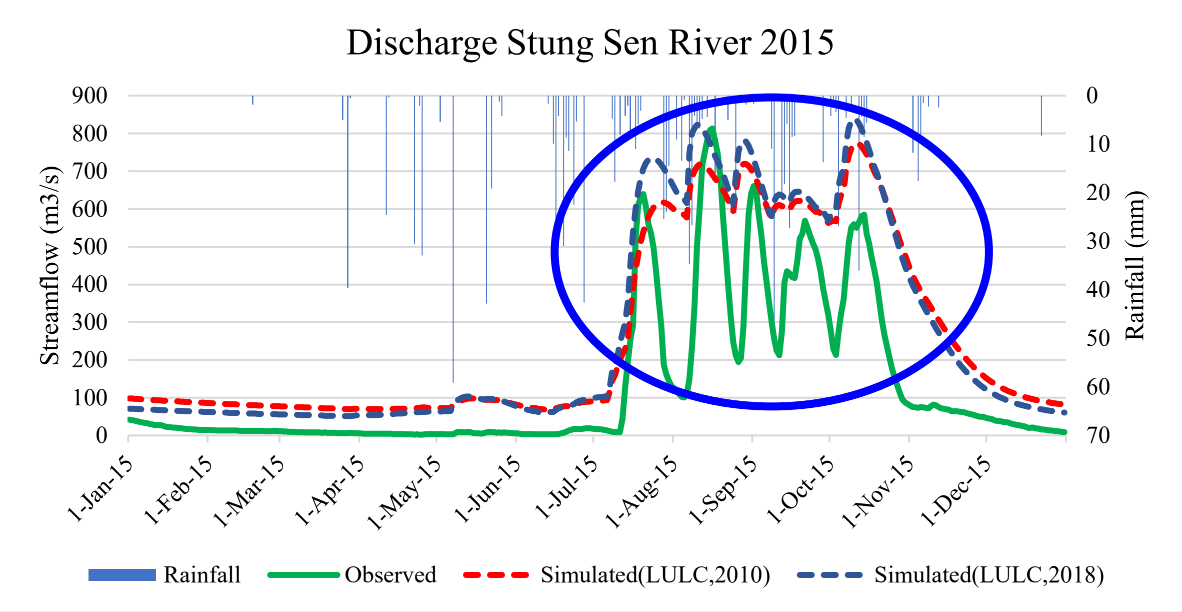
Monthly Water Balance Components from 2007-2021

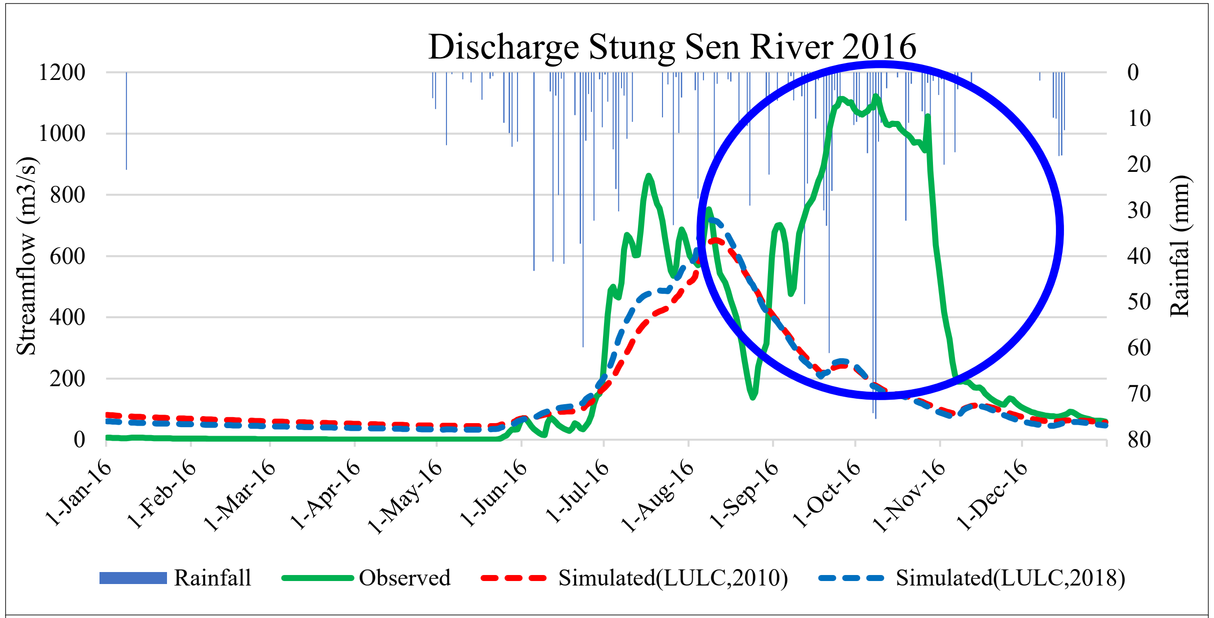


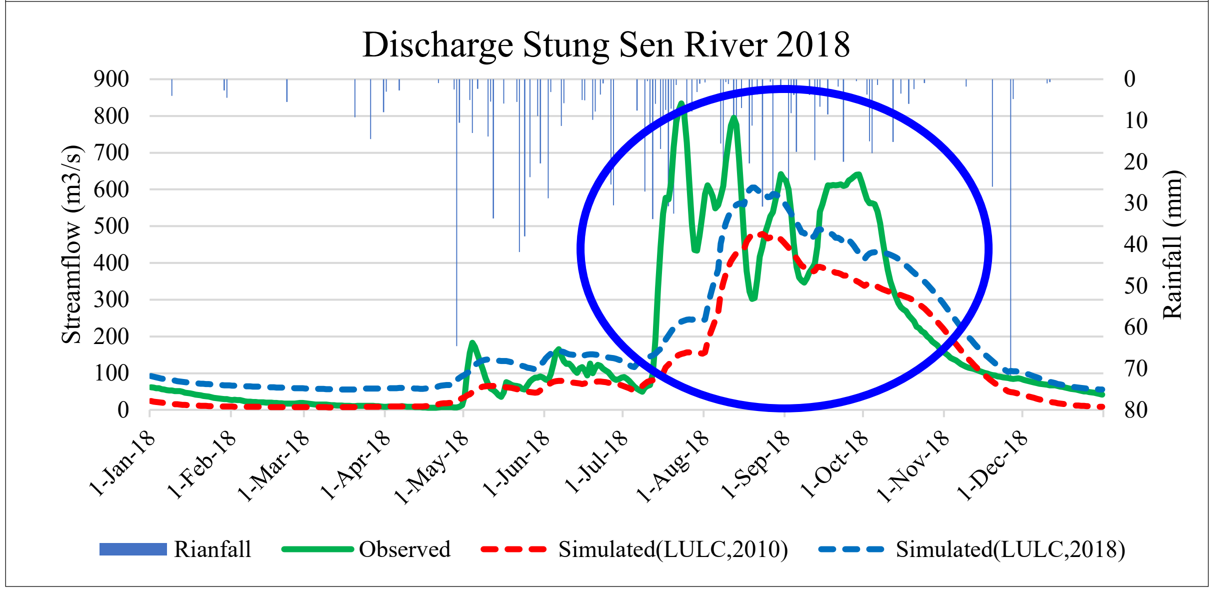
Monthly average hydrographs at Kampong Thom Station (2007-2021)

Monthly contribution of water balance components is **high in July, August, and September** during the wet season and low from **November to April during the dry season**. Evapotranspiration potential caused the most water flow from the basin among these components.

Discussions





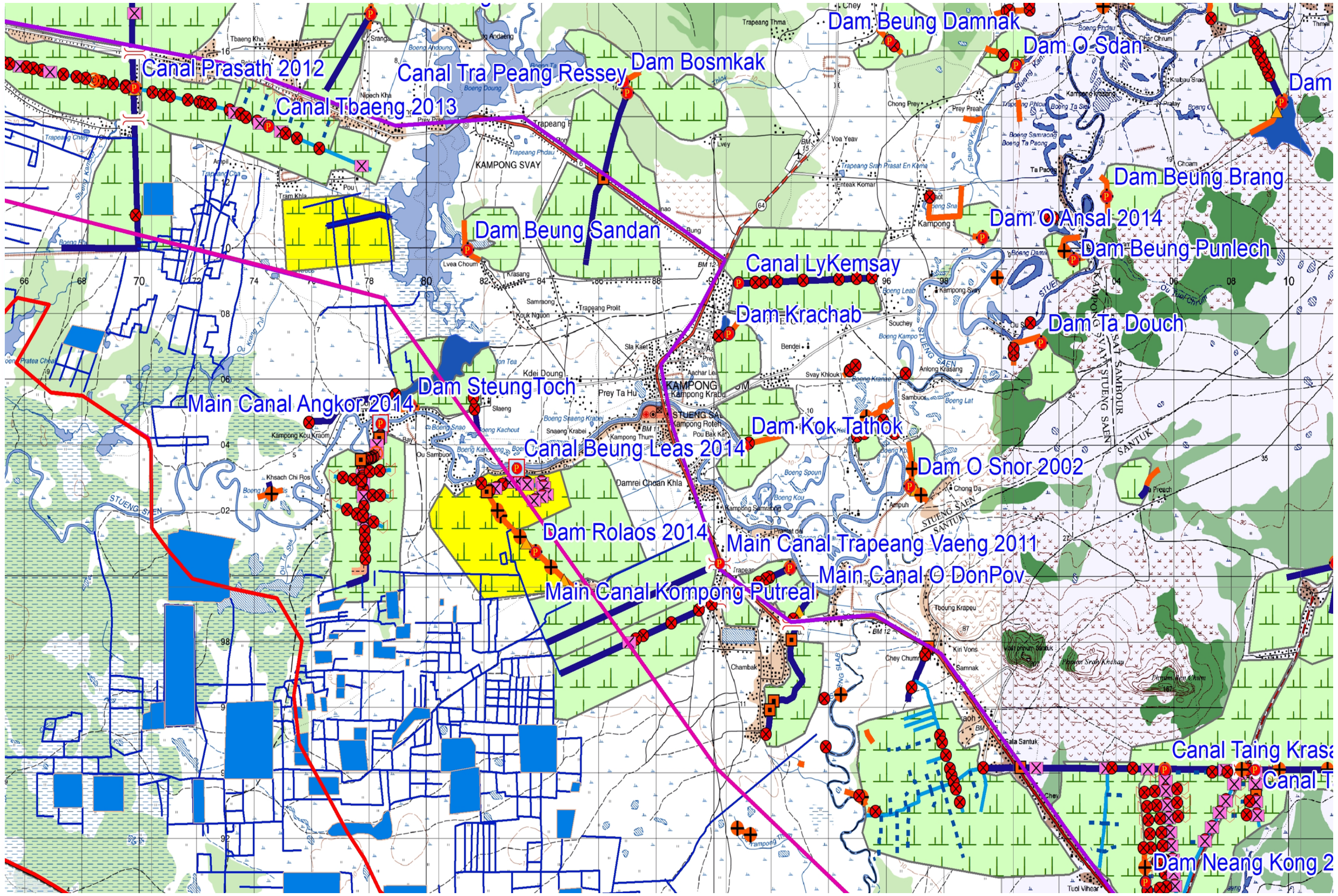


- **O Andeng dam** was constructed in 2013
- **O Touk dam, O Neak Takea dam, O Mean dam, O Chik dam and Krahom Kor dam** were rehabilitated to completion in 2015
- **O Leu irrigation** scheme was rehabilitated in 2018

MoWRAM & ADB, (2014 and 2019), and Green et al. (2019)

Main factors influencing on streamflow

Irrigation Development Map in Kampong Thom Province



Irrigation Schemes Map by local government, 2021

Poum Brasat dam

Raksa Hydropower Dam started construction in **2019**, upstream of the watershed, can store **256.9 million m3** during the rainy season.

Summary and Conclusion

- The study determined the possible effects of hydrological conditions by using the SWAT model, which was applicable for daily streamflow calibration and validation processes.

- The model produced the streamflow in an acceptable range from the beginning to the end of the seasonal streamflow.

- The annual distribution pattern **(2017-2021)** of streamflow fluctuated more than in the former period 2007-2016 due to natural environmental discharge. In 2017-2021 period, it would be highly influenced by **irrigation management and hydro-infrastructure.**

- The annual contribution of water balance components indicated a hydrologic alteration under the component of the watershed caused by changes in land-use over the long term. The watershed affected hydrological conditions and related to the local ecosystem.

Recommendations

- Hydrological gauge station should be installed in the upstream, inside other reservoirs, weirs, and main canal systems

- Irrigation infrastructure and dam development should be constructed in the upstream of river

- Integrated Water Resources Management should be implemented to introduce sustainable land management practices and land-use planning

- Examining the effects of dam operations and water balance computation for irrigation scale and the combination of climate change and land-use change should be considered for future research

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Thanks for your attention!