2015 International SWAT Conference

Assessment of Watershed Soundness by Water Balance Using SWAT Model for Han River Basin, South Korea

So Ra Ahn
(ahnsora@konkuk.ac.kr)
Ji Wan Lee, Chung Gil Jung, and Seong Joon Kim

Dept. of Civil & Environmental System Engineering
Konkuk University, SOUTH KOREA

KU KONKUK UNIVERSITY

Contents

- Introduction (Why this study?)
- Research procedure
- Study area
- SWAT model setup
  - ✓ Data for SWAT model evaluation
  - ✓ Spatial Calibration and Validation of the model
- Water balance analysis (vertical and horizontal)
- Impact of surface-groundwater exchange fluxes
- Watershed soundness assessment
- Summary and conclusions

Introduction (Why this study?)

- ***With increasing concerns surrounding the global climate change, there has been growing interests in the potential impacts to groundwater. It is expected that the predicted global changes in temperature and precipitation will alter the regional climates and water resources systems.***

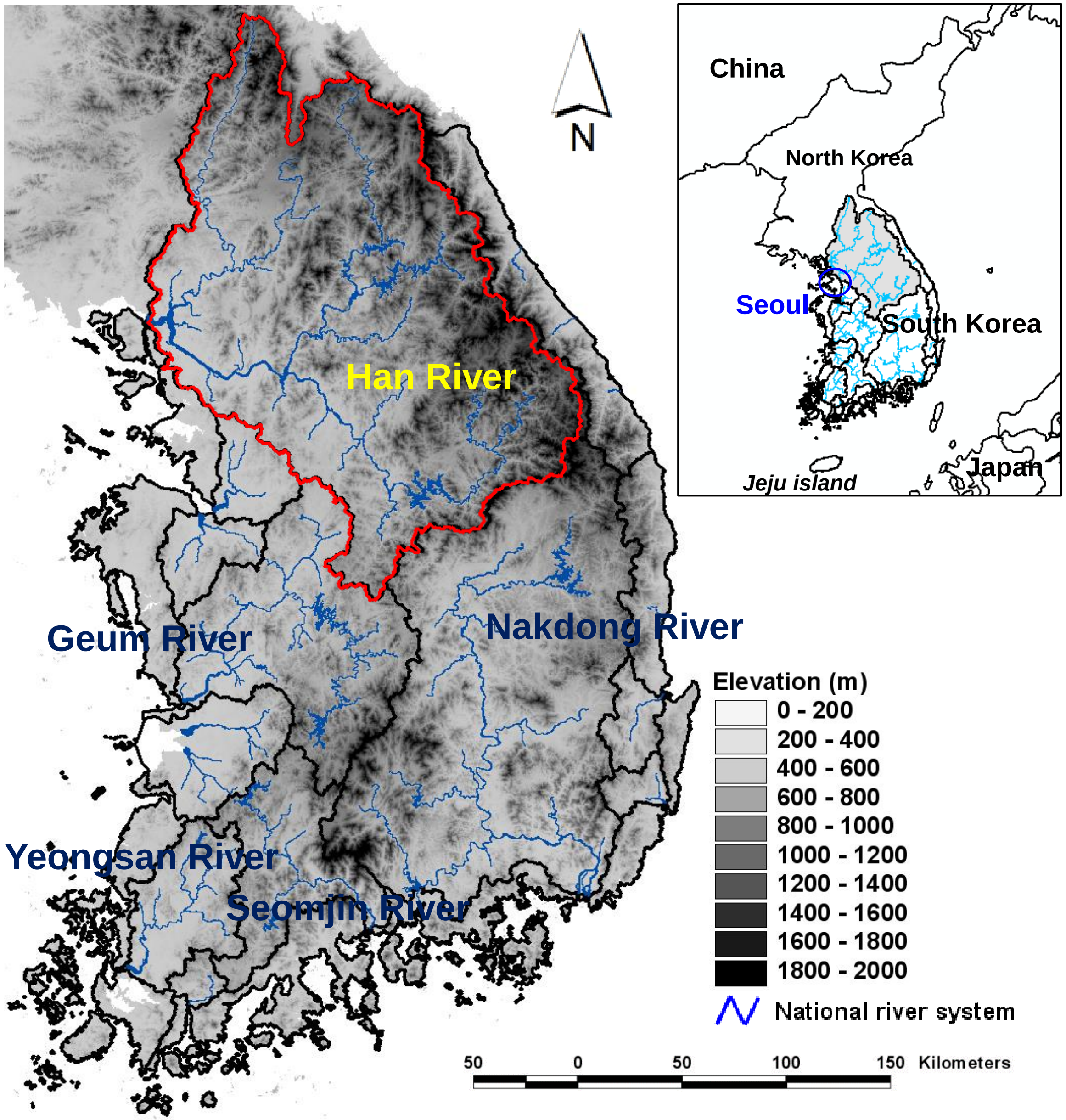
- ***Therefore, the accurate understanding of hydrologic processes occurring in basin is important to formulate the water resources policies, planning and management decisions in the region.***

- ***We need to simulate the components of hydrologic cycle to determine the impacts of land use changes, groundwater use, and dam operation of river basin on water resources policies, planning and management.***

- ***The purpose of this study is to investigate the impacts of surface water and groundwater interaction on water balance and groundwater recharge for watershed soundness assessment of Han River basin (34,148 km^2) in South Korea by SWAT modeling.***

KONKUK University
KRIEL
Regional Information Engineering Lab.

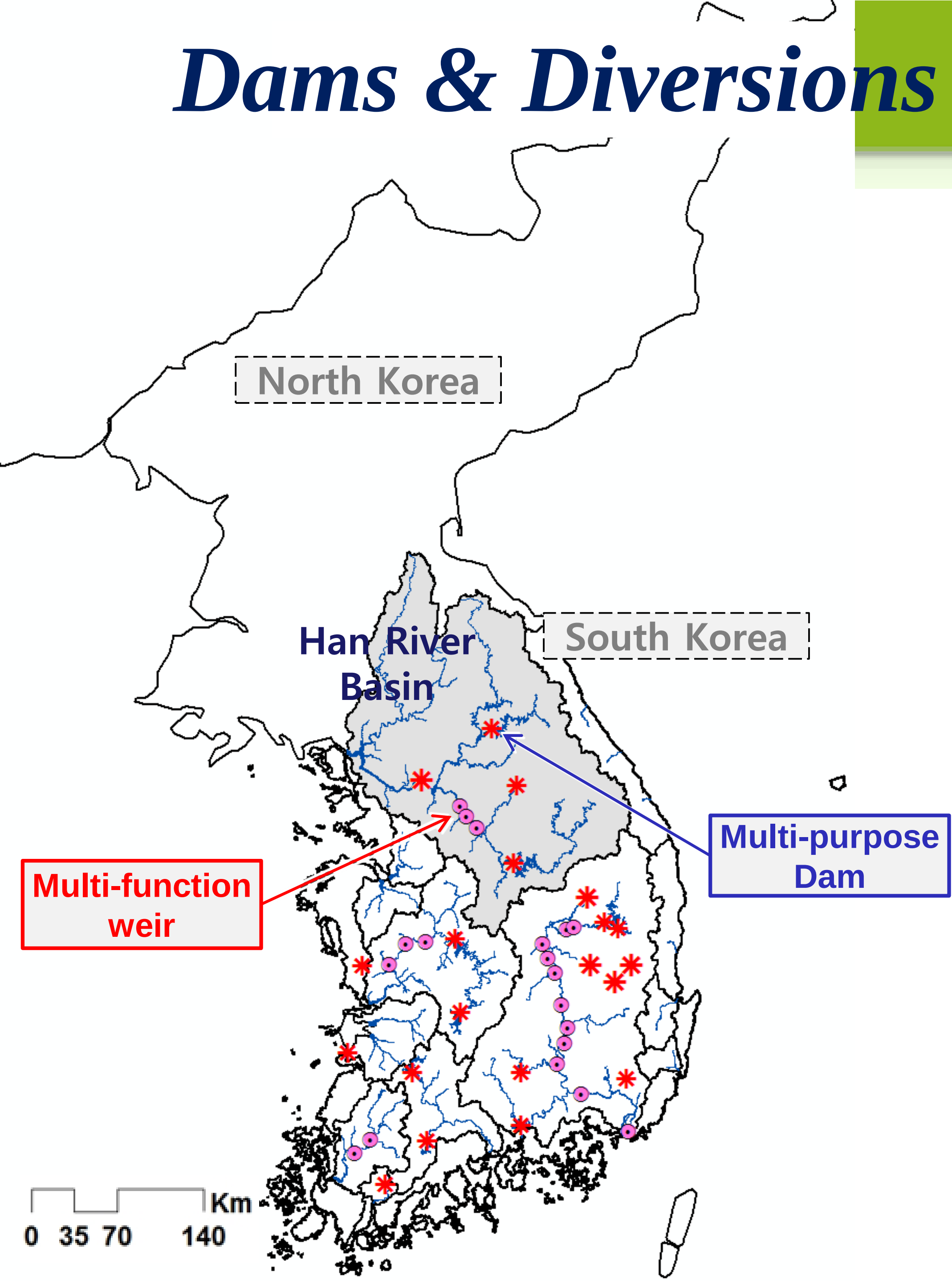
5 Major River basins of South Korea



- ***5 Major river basins in our country (Han, Geum, Yeongsan, Seomjin, and Nakdong)***
- ***The global warming is now warning the management of streamflow (intensify drought and flood)***
- ***Need to evaluate the availability water resource by water balance analysis***
- ***From the evaluation, find out some insight and prepare proper direction for water management system***

KONKUK University RIEL Regional Information Engineering Lab.

Dams & Diversions of South Korea



- *At present, we have **20 multipurpose dams** and **19 multifunction weirs** in South Korea.*
- *They have been successfully managed by both Korea Water Resources Corporation (**K-water**) and Korea Hydro & Nuclear Power Co. Ltd. (**KHNP**) **to fulfill water demands, flood control and hydropower generation.***
- *Korea needs fundamental countermeasures to mitigate damages from repetitive floods and droughts caused by climate change.*

KONKUK University RIEL Regional Information Engineering Lab.

Research procedure

Model Input

Observed Data

- *Weather data (1984-2014)*
- *Evapotranspiration (2009-2013)*
- *Soil moisture (2009-2013)*
- *Groundwater level (2009-2013)*

GIS Data

- *DEM, Soil,* Land use

Multipurpose Dam Data

- *4 multipurpose water supply dams (1984-2014)*
  - *Dam inflow, storage, release*
- *3 multifunction weirs (2012-2014)*
  - *Dam inflow, storage, release*

Model Process Dynamics

SWAT Model

- *Model run (1984-2014)*
- *Warm-up (1984)*
- *Calibration (2005-2009) and validation (2010-2014)*
  - *Dam & weir inflow*
  - *Dam & weir storage*
  - *Evapotranspiration*
  - *Soil moisture*
  - *Groundwater level variation*
- *Dam operation (2005-2014)*

Surface Processes

- *Vertical water budget : infiltration, evapotranspiration*
- *Horizontal water transfer: surface runoff*

↕

Soil Water Dynamics

- *Vertical water budget : percolation, soil water storage,*
- *Horizontal water transfer: lateral flow*

↕

Groundwater Dynamics

- *Vertical water budget : groundwater revap, groundwater recharge,*
- *Horizontal water transfer: return flow*

Model Results

Analysis of Water Balance → **Watershed Soundness Assessment**

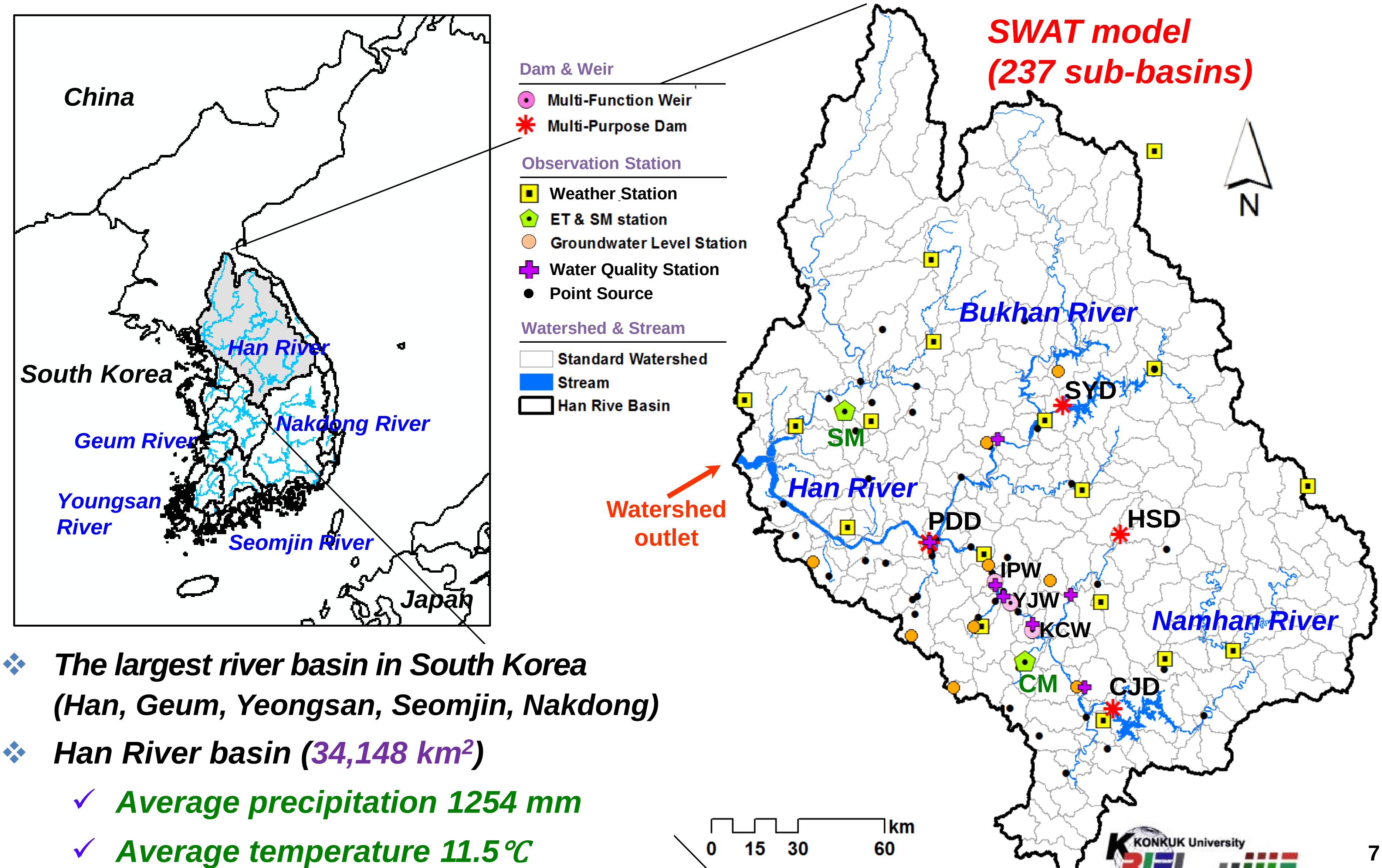
Analysis of Water Balance:

- *Vertical water budget and horizontal water transfers*
- *Surface-groundwater exchange fluxes*

Watershed Soundness Assessment:

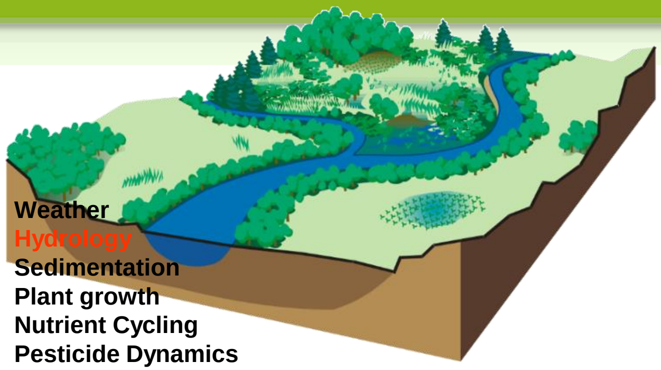
- *Normalized metric value → sub-index*
- *Watershed health index*

Study area



- *The largest river basin in South Korea (Han, Geum, Yeongsan, Seomjin, Nakdong)*
- *Han River basin (34,148 km²)*
  - ✓ *Average precipitation 1254 mm*
  - ✓ *Average temperature 11.5℃*

SWAT model (Soil and Water Assessment Tool)

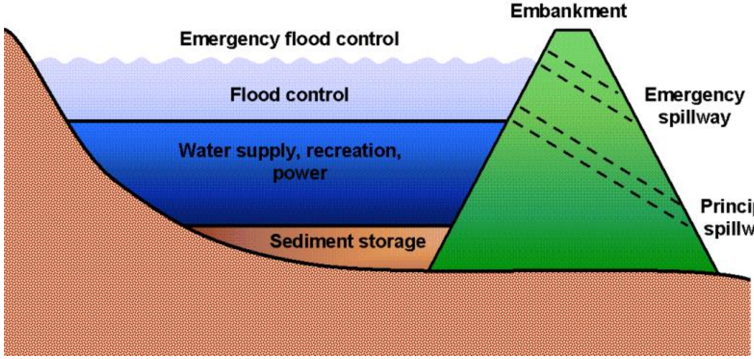


- Weather
- Hydrology
- Sedimentation
- Plant growth
- Nutrient Cycling
- Pesticide Dynamics
- Management
- Bacteria

Water balance

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

SW_t = Final soil water content (mm)
SW_0 = Initial soil water content on day i (mm)
R_{day} = Amount of precipitation on day i (mm)
Q_{surf} = Amount of surface runoff on day i (mm)
E_a = Amount of evapotranspiration on day i (mm)
W_{seep} = Amount of water entering the vadose zone from the soil profile on day i (mm)
Q_{gw} = Amount of return flow on day i (mm)



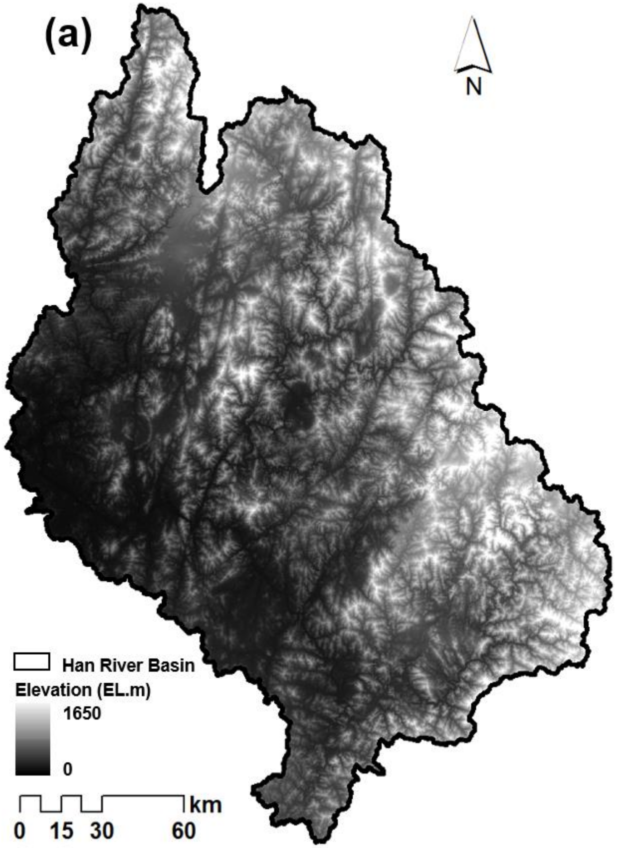
Reservoir

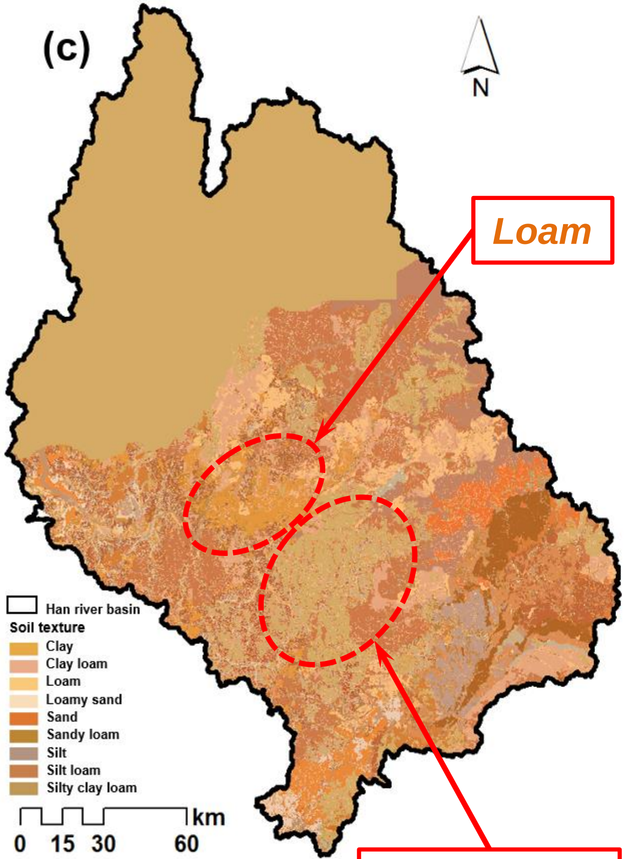
$$V = V_{stored} + V_{flowin} - V_{flowout} + V_{pcp} - V_{evap} - V_{seep}$$

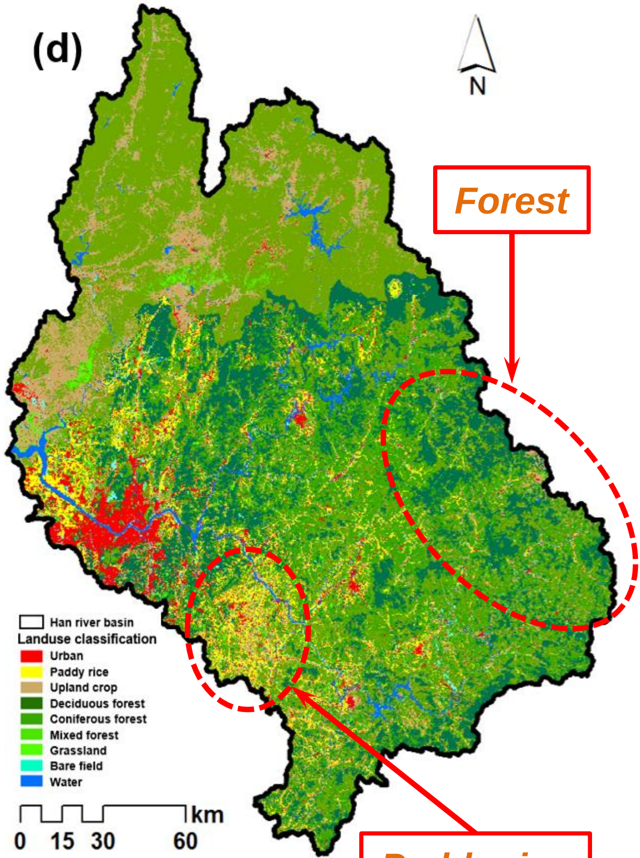
V = volume of water in the impoundment at the end of the day (m3H2O)
V_{stored} = volume of water stored in the water body at the beginning of the day (m3 H2O)
V_{flowin} = volume of water entering the water body during the day (m3 H2O)
V_{flwout} = volume of water flowing out of the water body during the day (m3 H2O)
V_{pcp} = volume of precipitation falling on the water body during the day (m3 H2O)
V_{evap} = volume of water removed from the water body by evaporation during the day (m3 H2O)
V_{seep} =volume of water lost from the water body by seepage (m3 H2O).

Data for SWAT model evaluation

GIS data



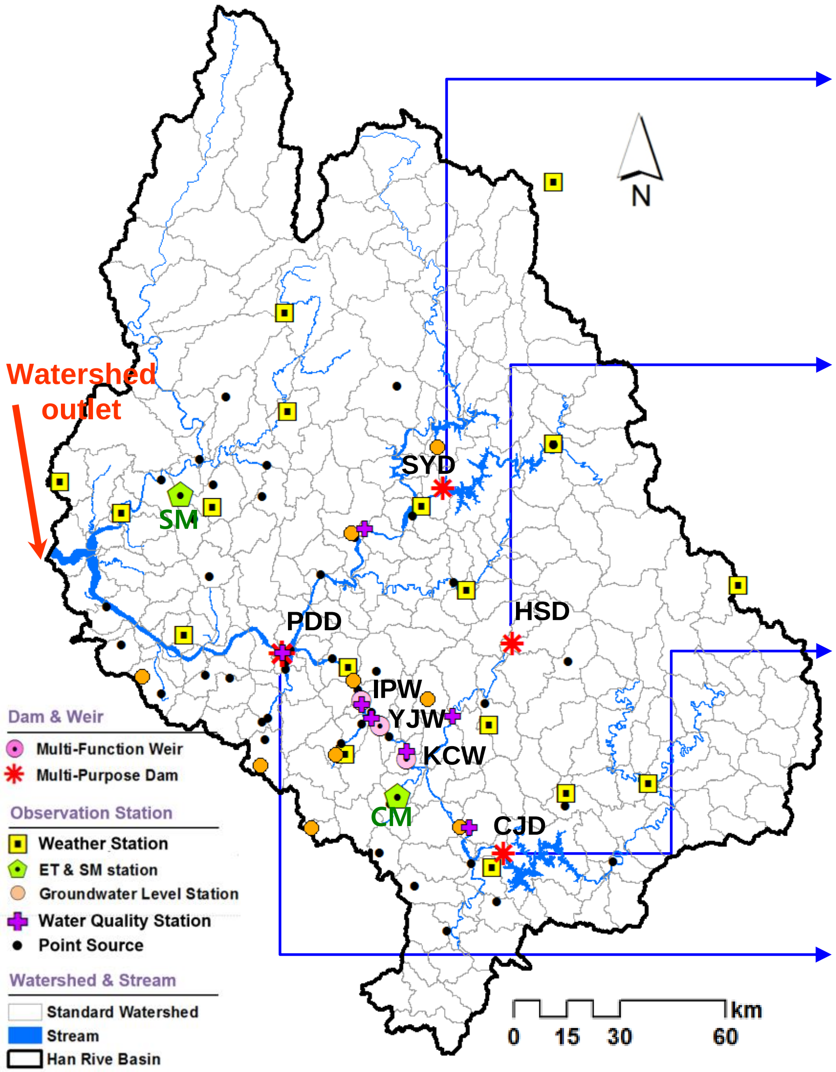


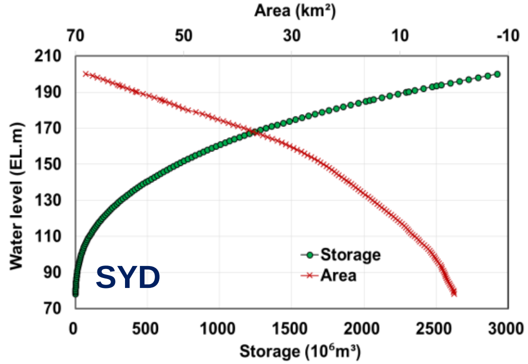


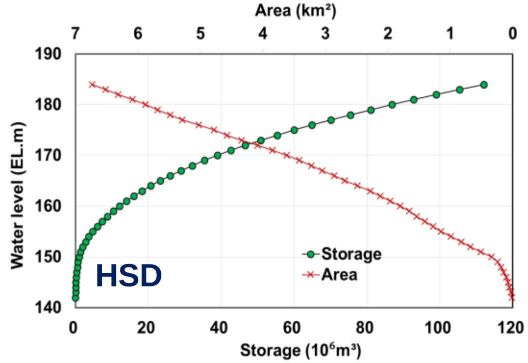
KONKUK University
KRIEL
Regional Information Engineering Lab.

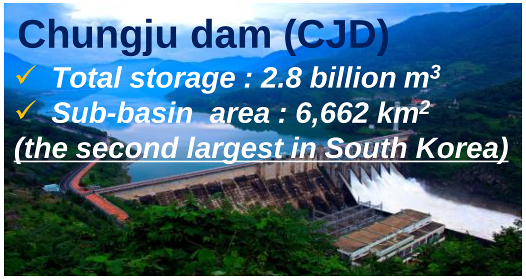
Data for SWAT model evaluation

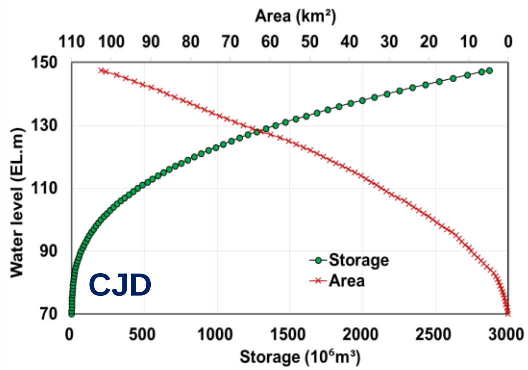
4 Multipurpose dam data (area-level and storage-level relationship curve)

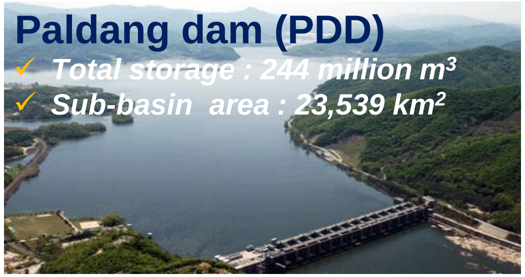






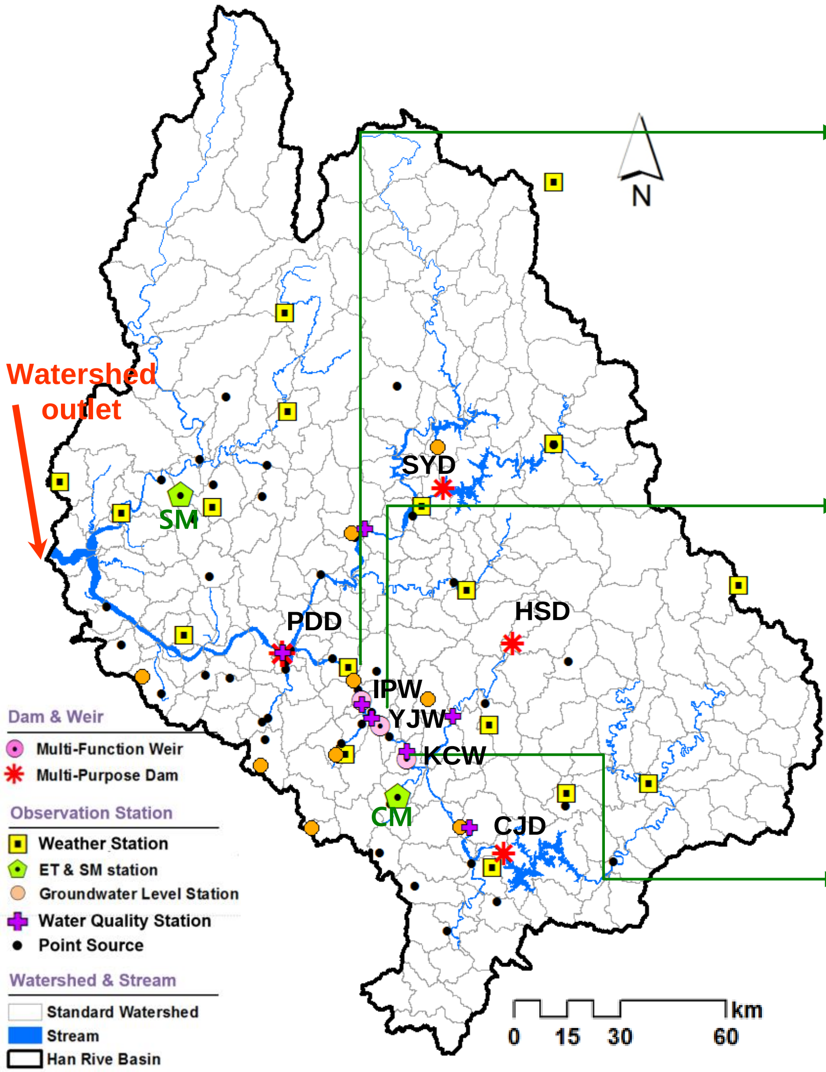


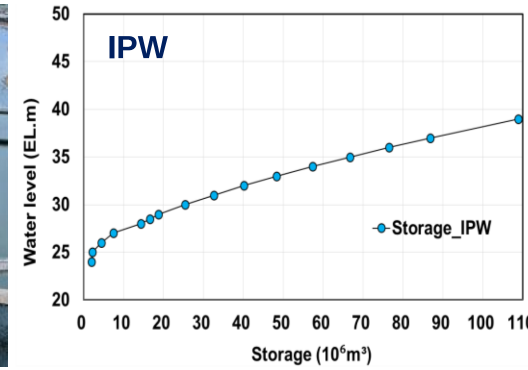


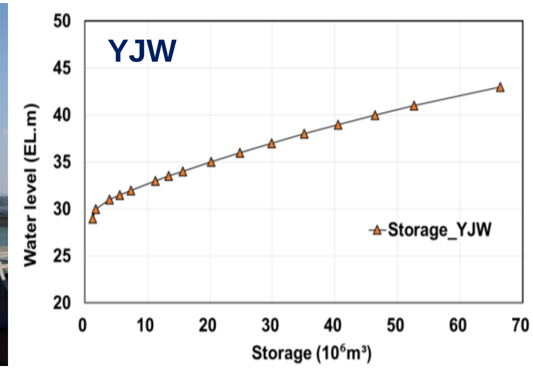


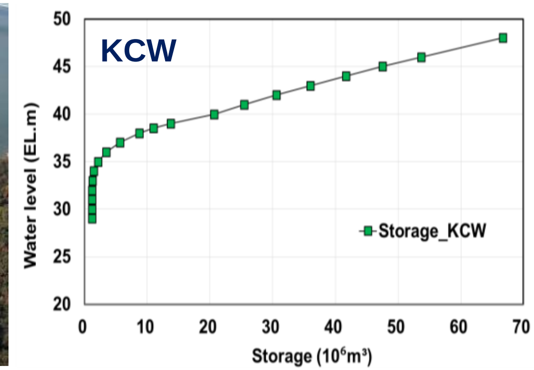
Data for SWAT model evaluation

3 Multifunction weir data (area-level and storage-level relationship curve)





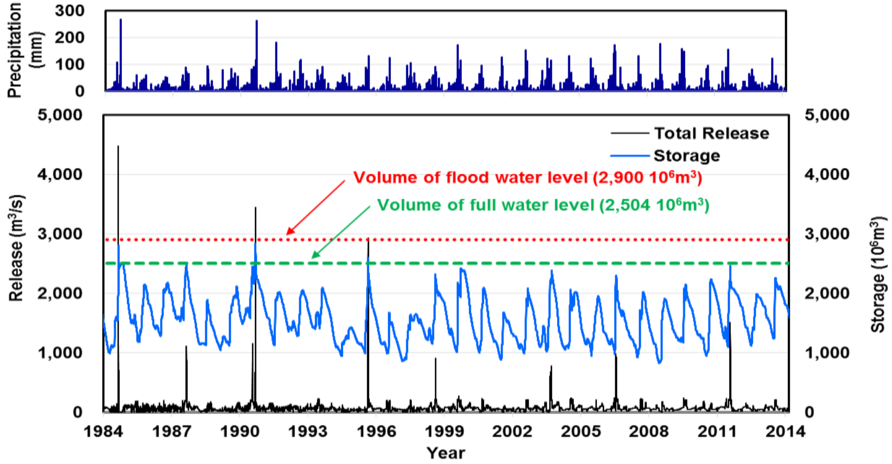




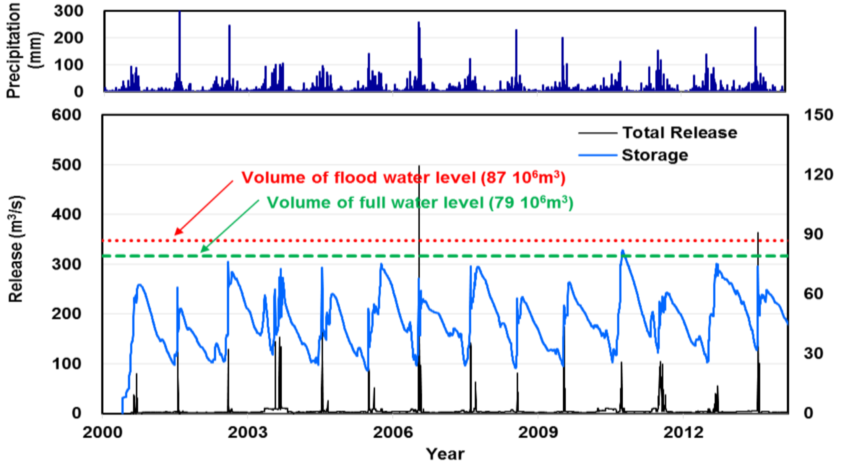
Data for SWAT model evaluation

4 Multipurpose dam data (release and storage : 1984-2014)

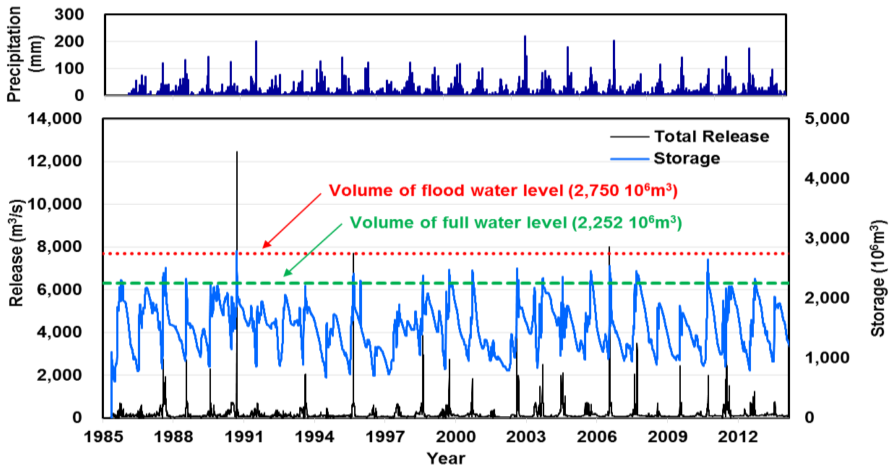
Soyang dam (SYD)



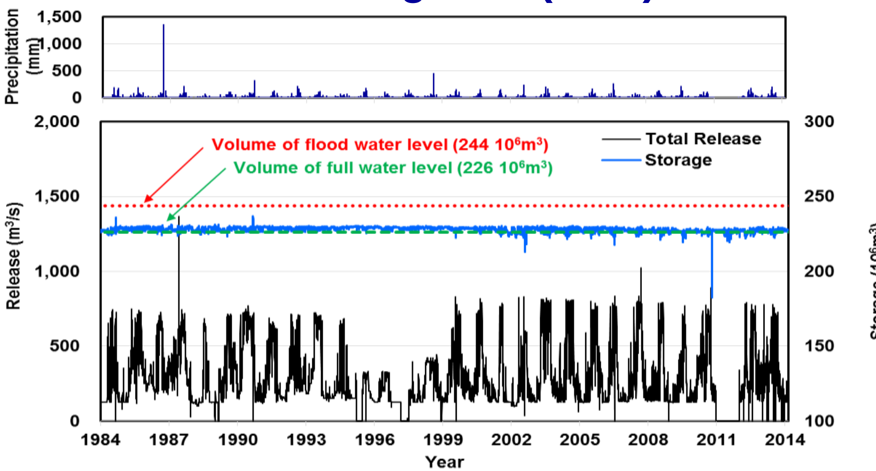
Hoengseong (HSD)



Chungju dam (CJD)



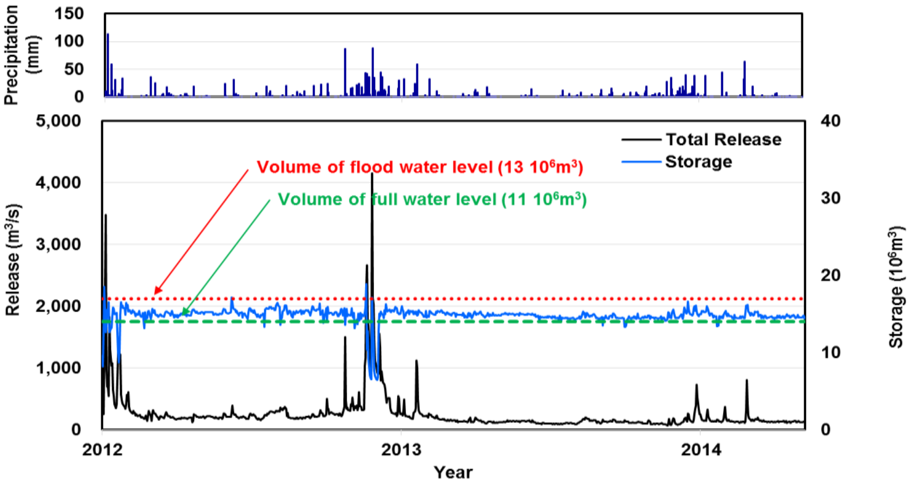
Paldang dam (PDD)



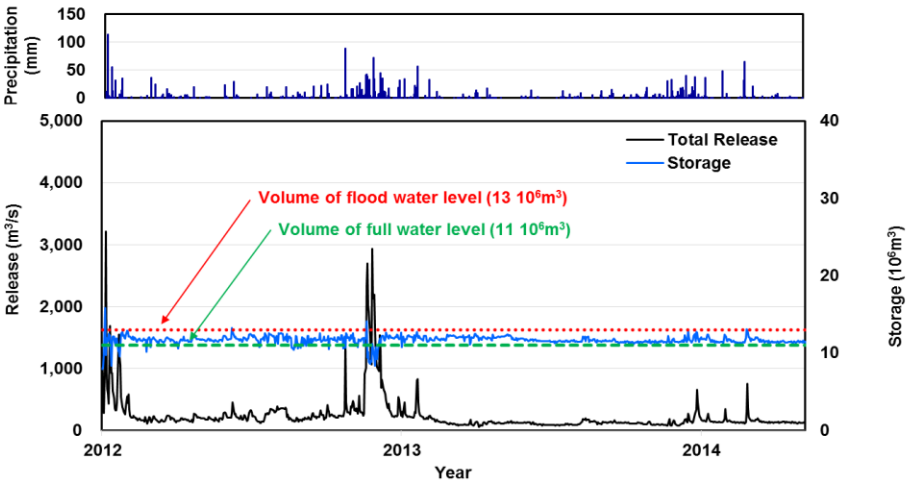
Data for SWAT model evaluation

3 Multifunction weir data (release and storage : 2012-2014)

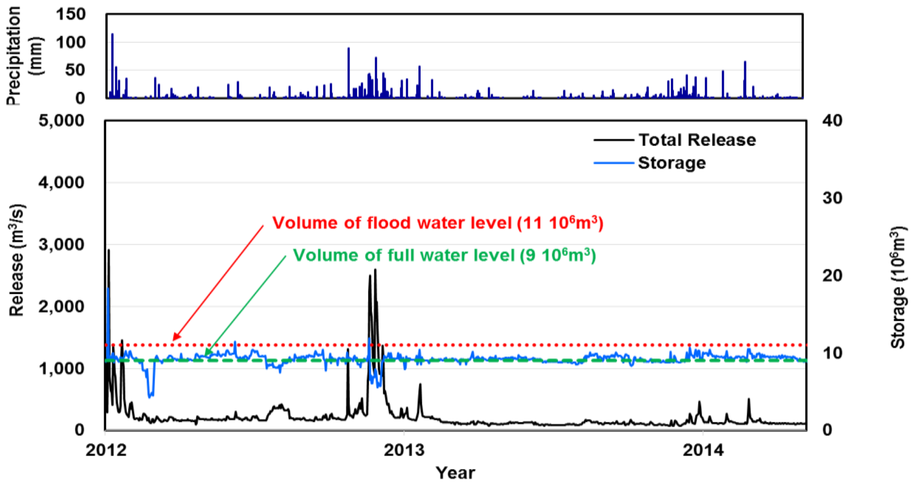
Ipo weir (IPW)



Yeoju weir (YJW)



Kangcheon wier (KCW)

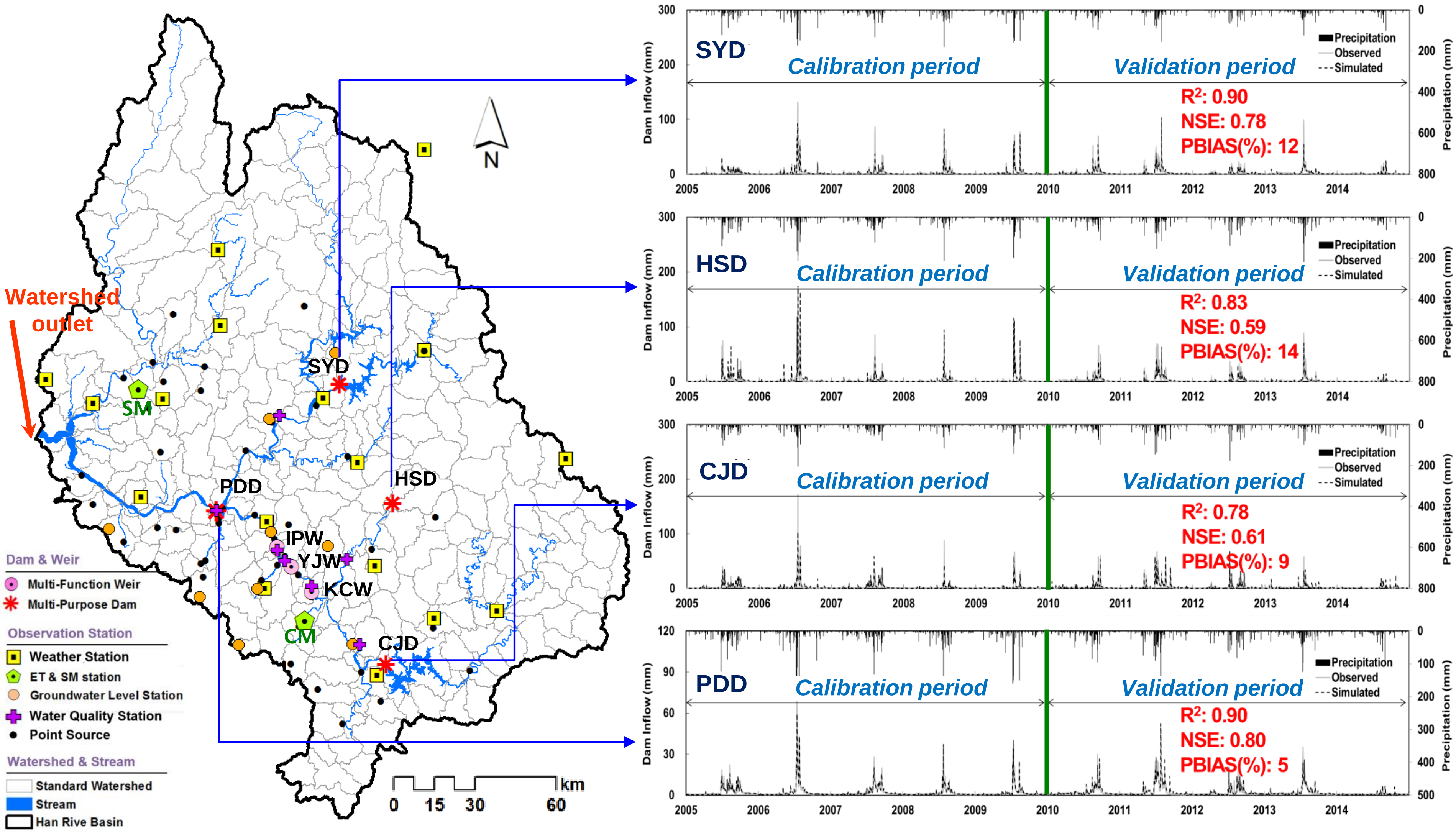


KONKUK University
Regional Information Engineering Lab.

Model calibration and validation

Observed vs. simulated streamflow results of model calibration and validation

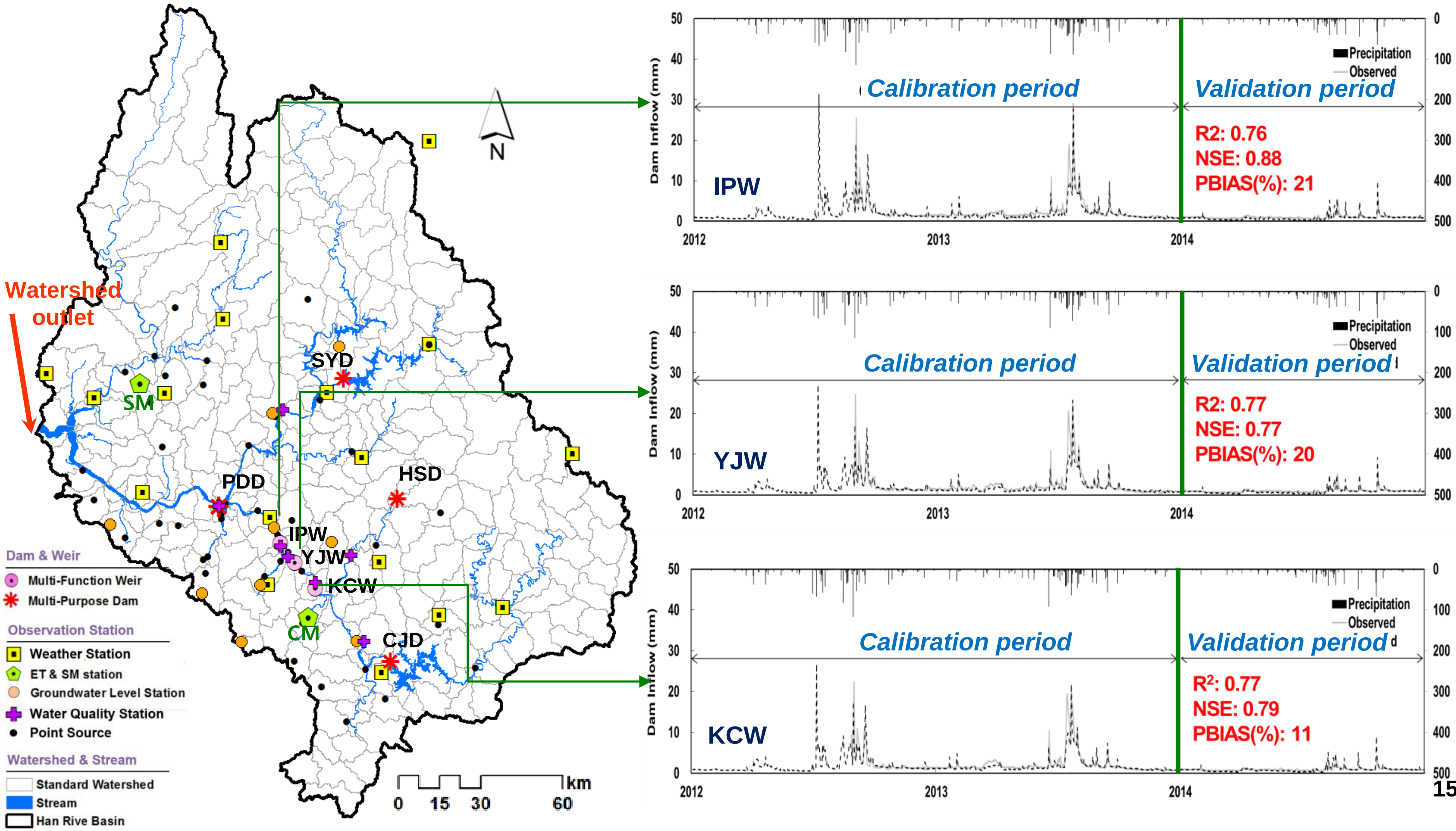
- ✓ **Calibration : 5 years (2005-2009) / Validation : 5 years (2010-2014)**



Model calibration and validation

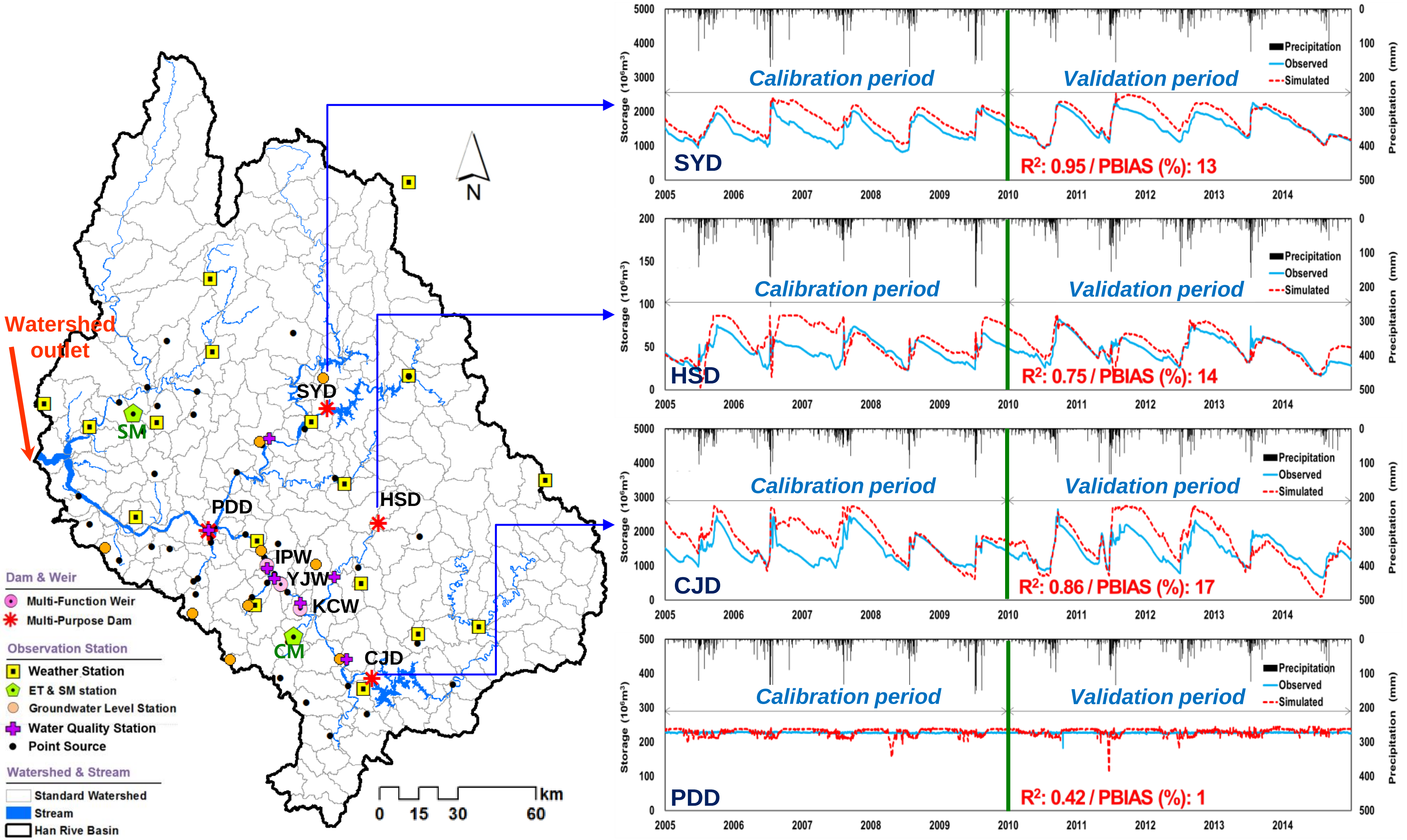
Observed vs. simulated streamflow results of model calibration and validation

✓ **Calibration : 2 years (2012-2013) / Validation : 1 year (2014)**



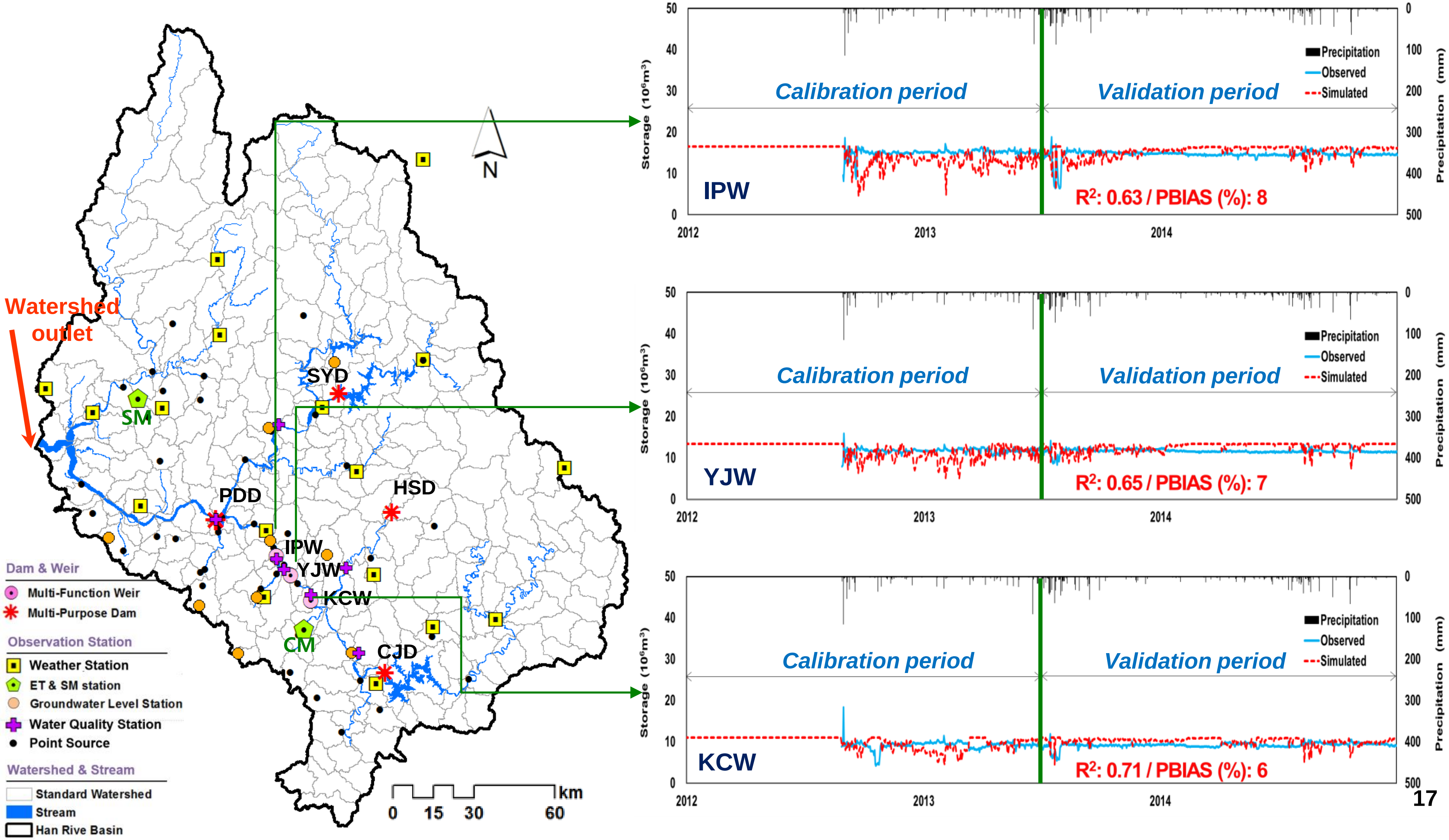
Model calibration and validation

Fitted results of 4 multipurpose dams storage



Model calibration and validation

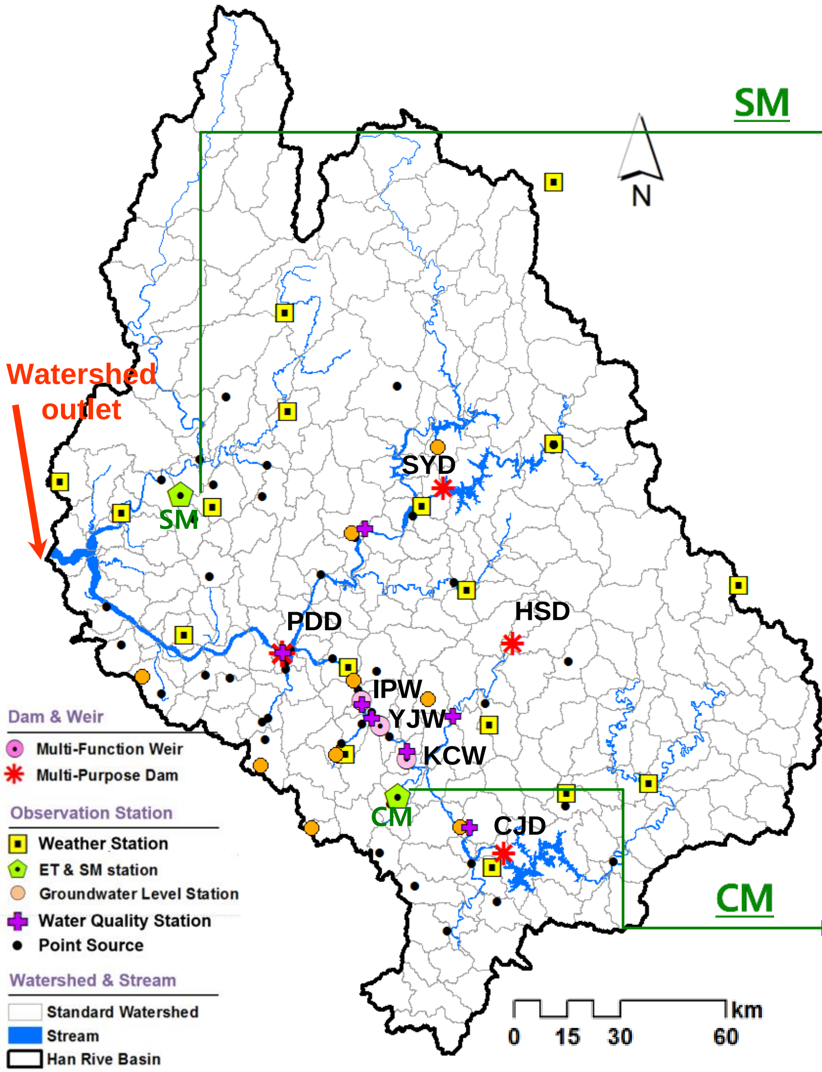
Fitted results of 3 multifunction weirs storage

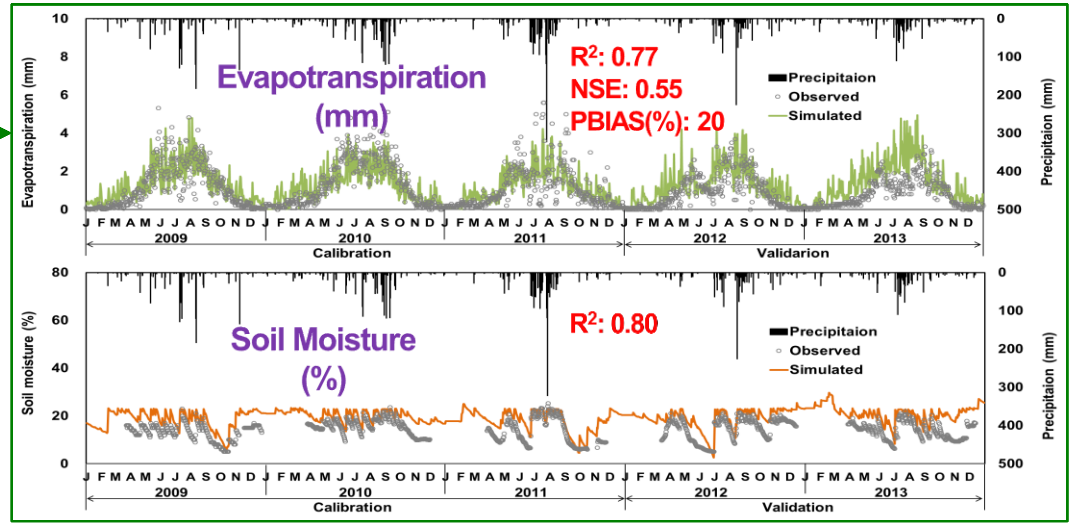


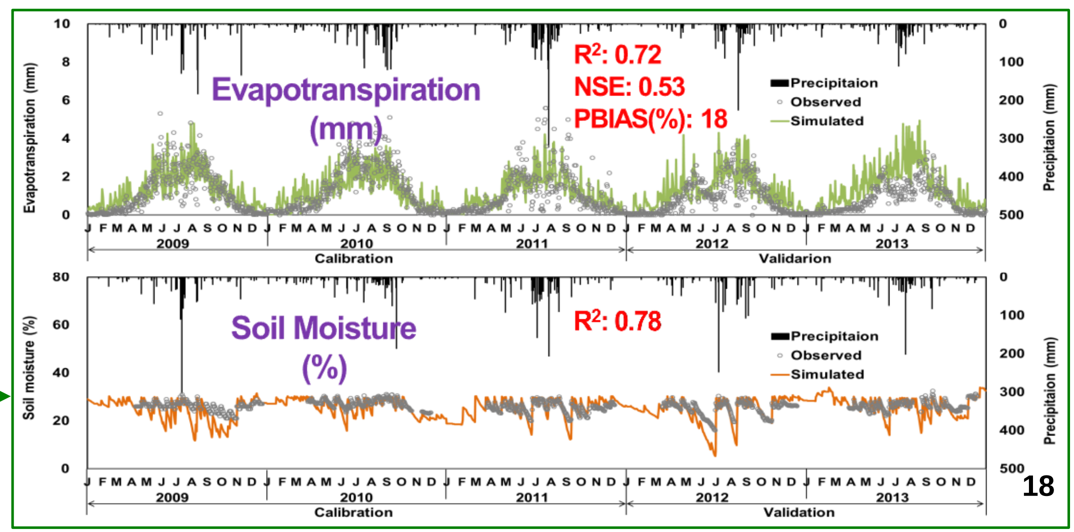
Model calibration and validation

Observed vs. simulated ET & SM results of model calibration and validation

- ✓ Calibration : 3 years (2009-2011) / Validation : 2 years (2012-2013)



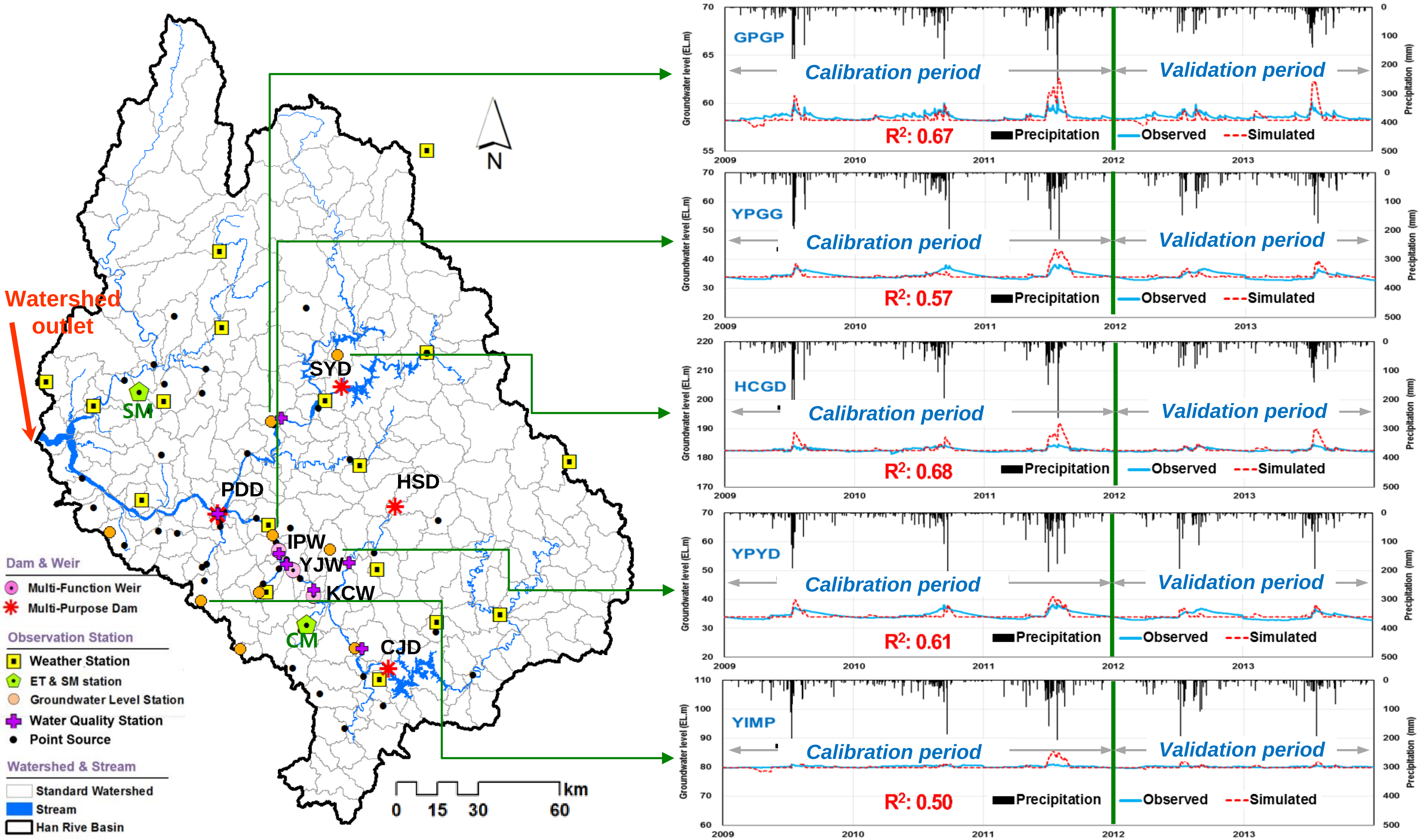




Model calibration and validation

Observed vs. simulated groundwater level variation results of model calibration and validation

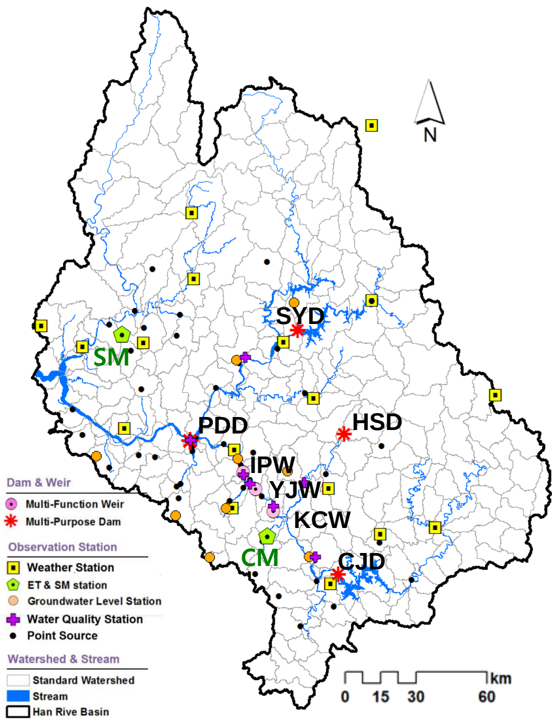
- ✓ **Calibration : 3 years (2009-2011) / Validation : 2 years (2012-2013)**

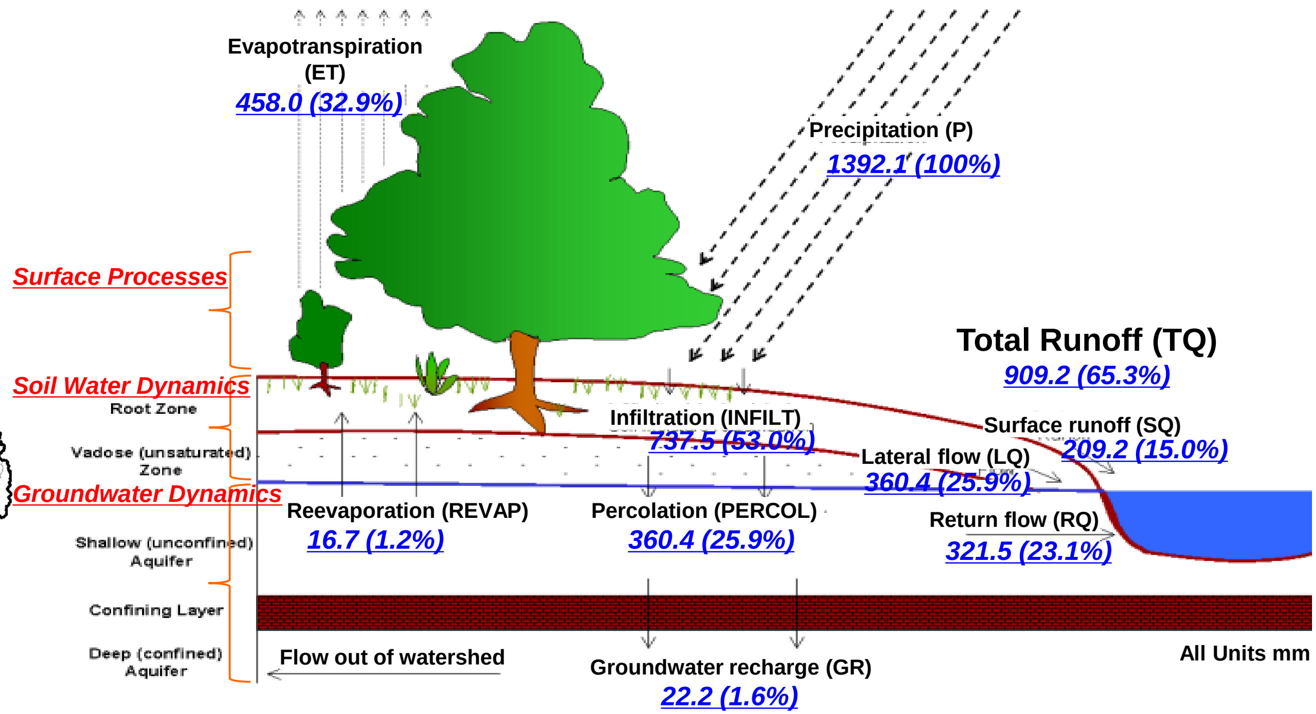


Water balance analysis

River basin water balance (water balance ratios based on precipitation)

✓ 30 years (1985-2014) simulated by SWAT



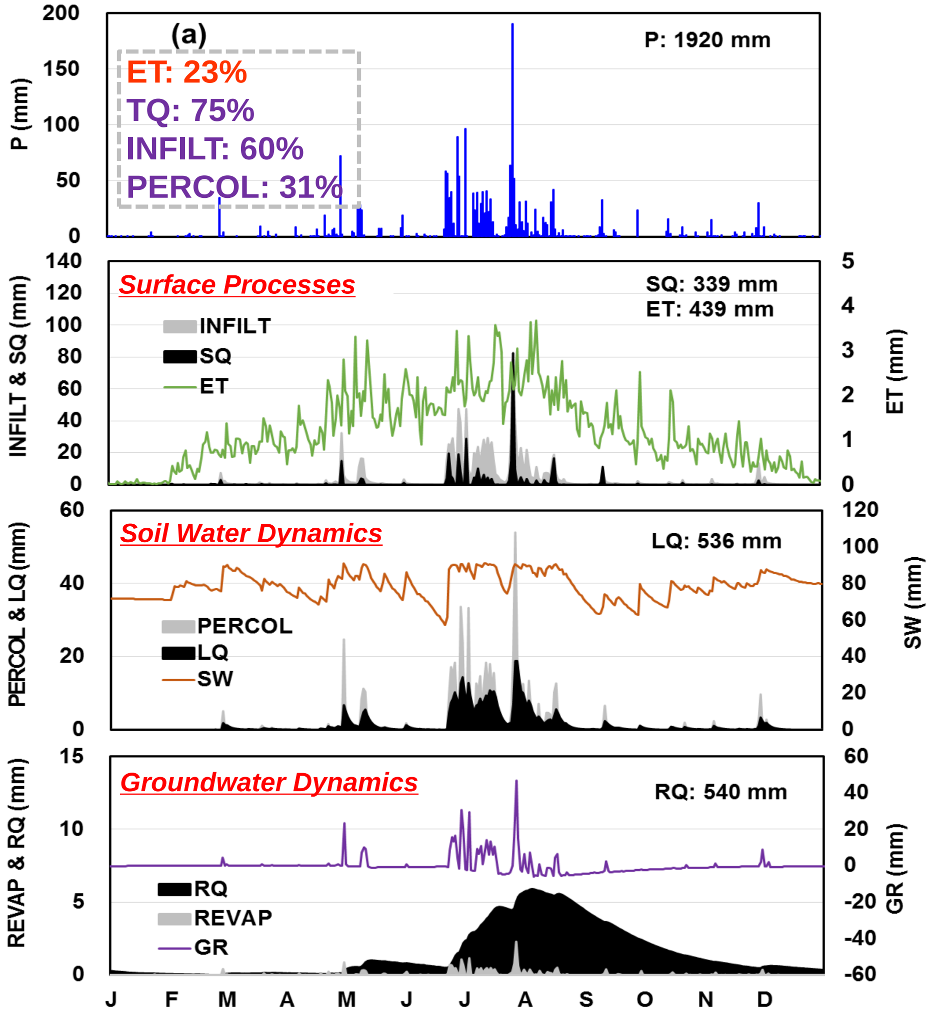


Period	Total		Surface Processes			Soil Water Dynamics			Groundwater Dynamics		
	P (mm)	TQ (mm)	INFILT (mm)	ET (mm)	SQ (mm)	PERCOL (mm)	SW (mm)	LQ (mm)	REVAP (mm)	GR (mm)	RQ (mm)
Rainy Season (Jun-Sept)	1004.5	644.0 (66%)	577.9	249.8 (25%)	179.4 (18%)	258.9	77.8	280.0 (28%)	12.1	69.2	204.7 (20%)
Dry season (Oct-May)	387.6	227.0 (59%)	159.6	208.2 (54%) +29%	29.8 (8%)	74.9	80.8	80.4 (21%)	4.7	-41.0	106.8 (30%) +10%
Annual	1392.1	909.2 (65%)	737.5	458.0 (33%)	209.2 (15%)	360.4	79.8	360.4 (26%)	16.7	22.2	321.5 (23%)

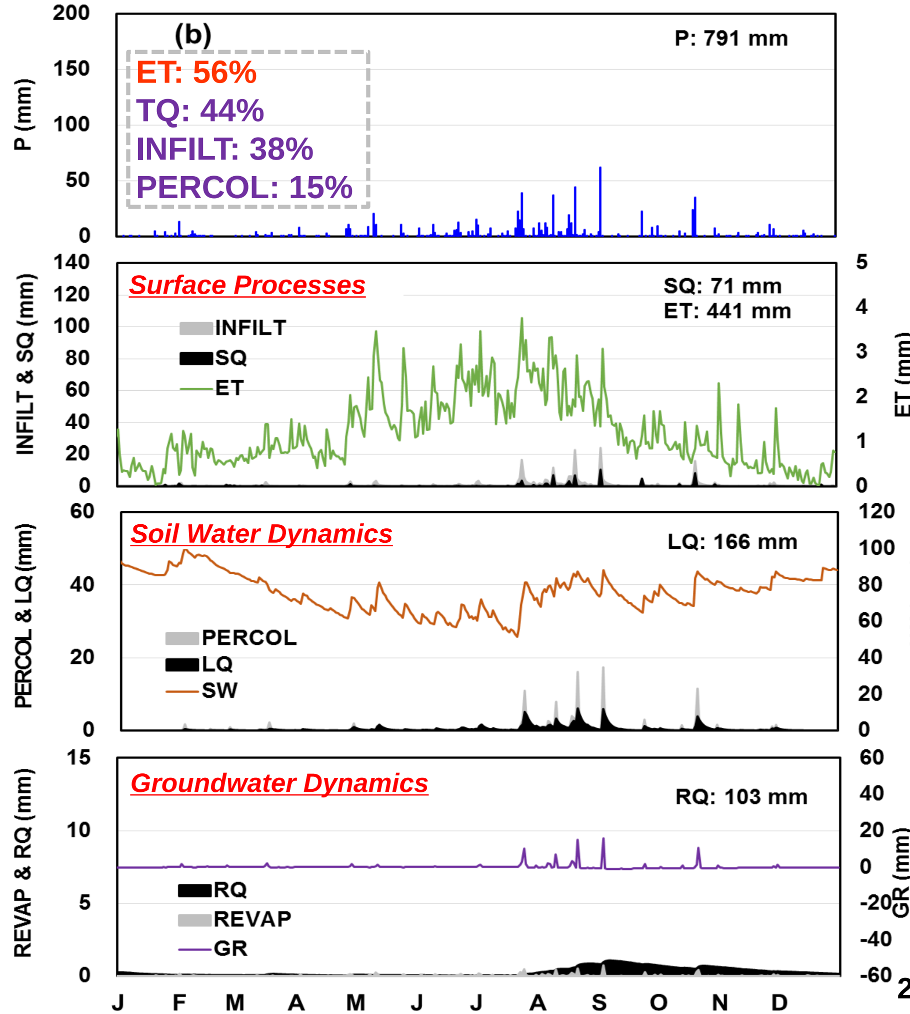
Water balance analysis

Daily water balance (between surface water and groundwater)

Flood year (2011)



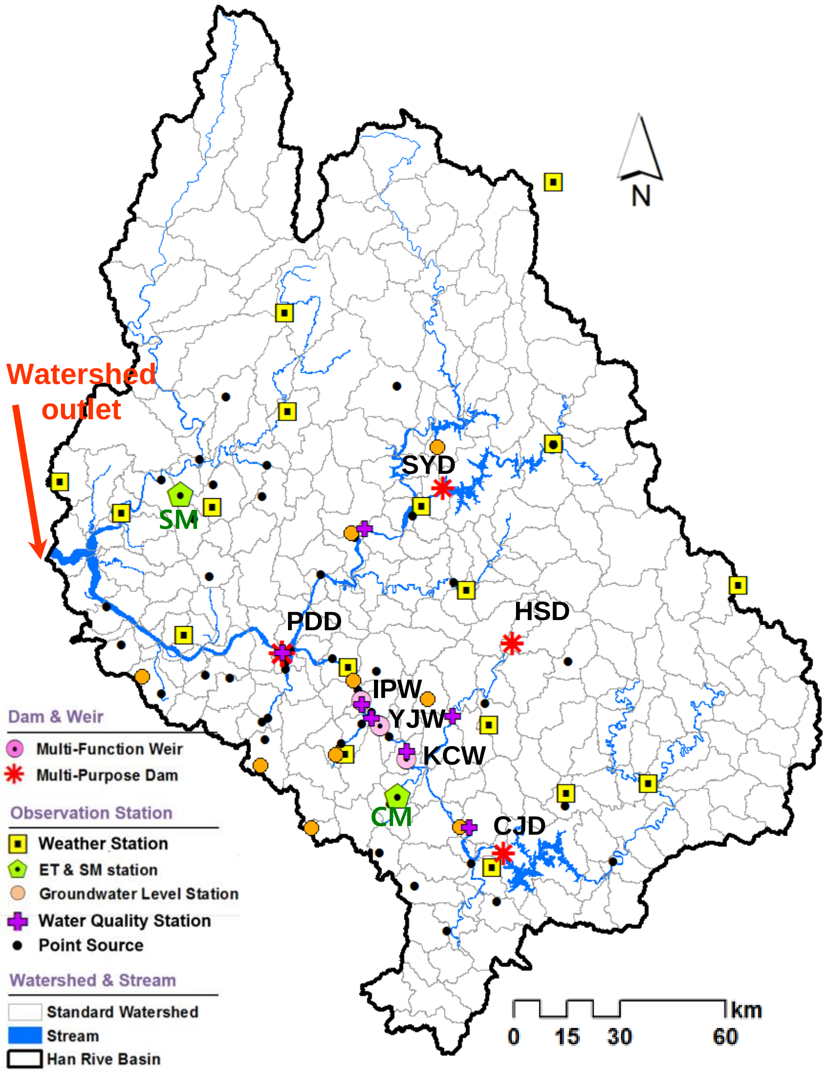
Drought year (2014)

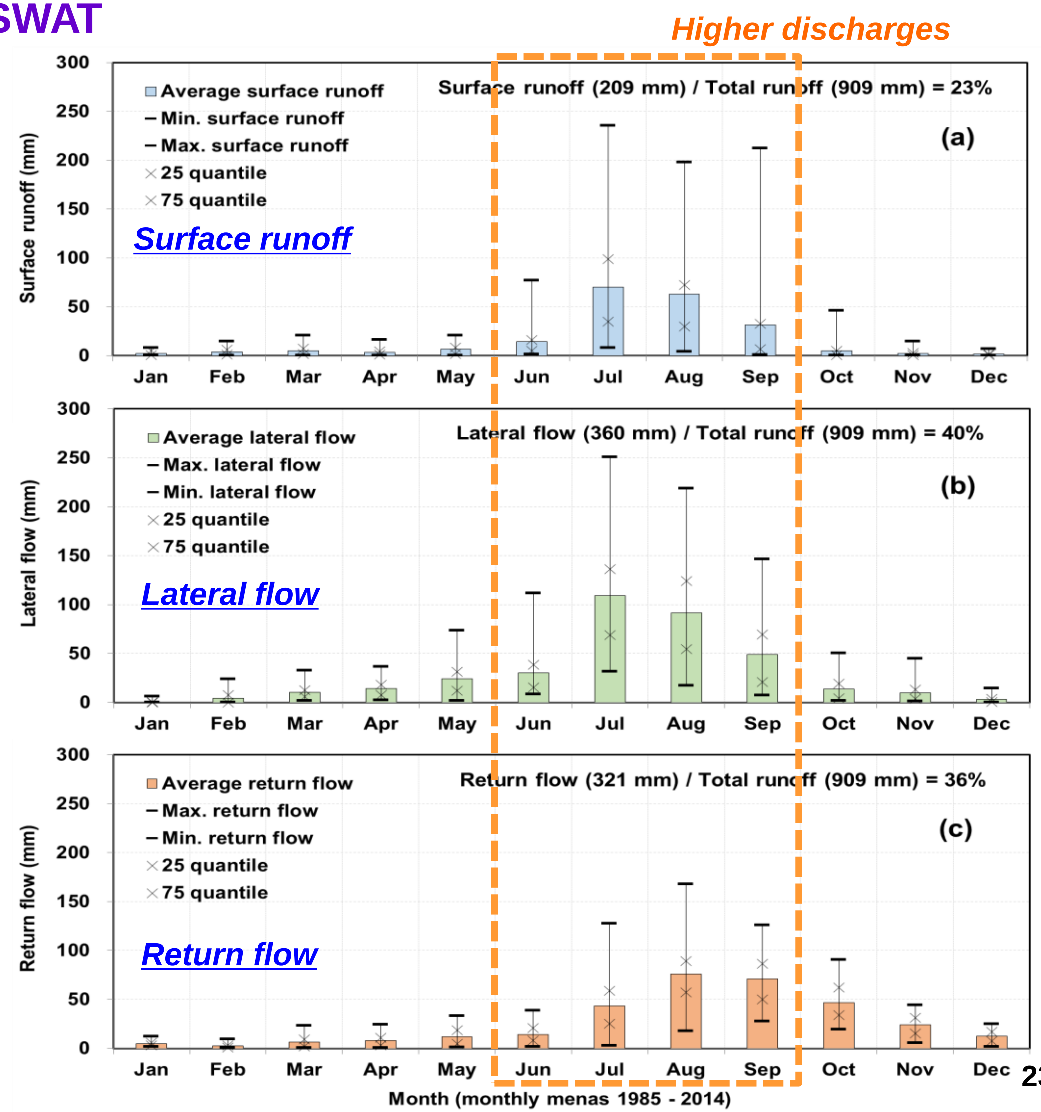


Impact of surface-groundwater exchange fluxes

Monthly average discharge (surface runoff, lateral flow, and return flow)

✓ 30 years (1985-2014) simulated by SWAT

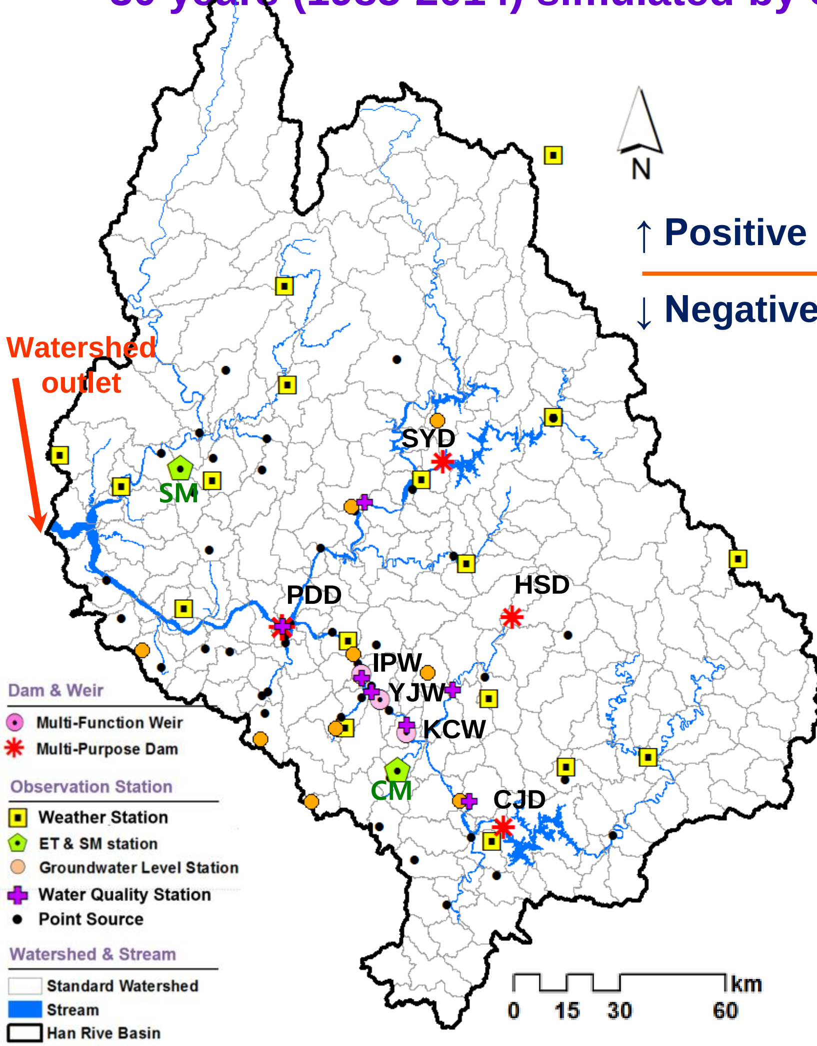


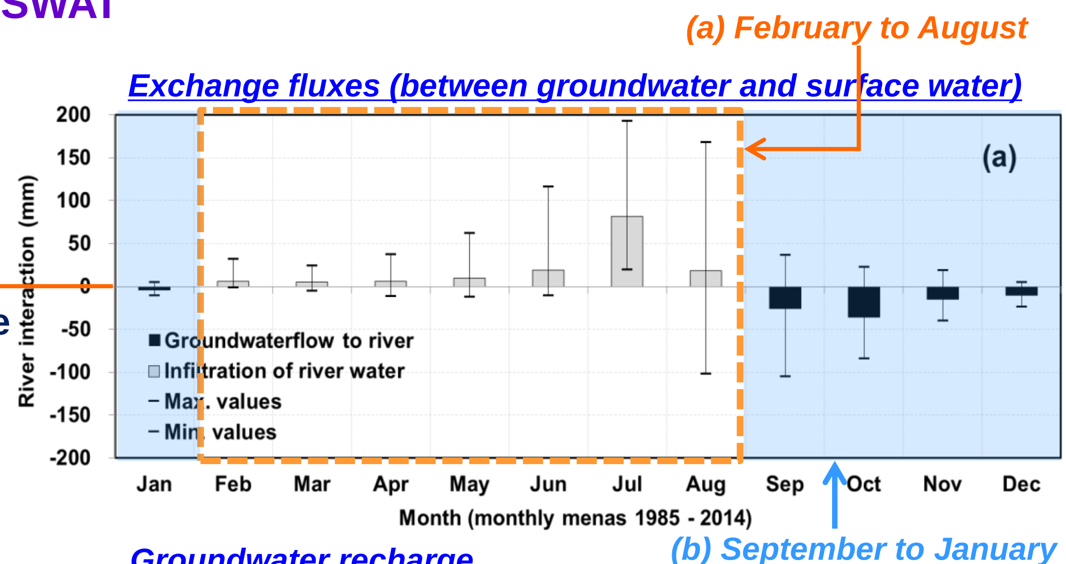


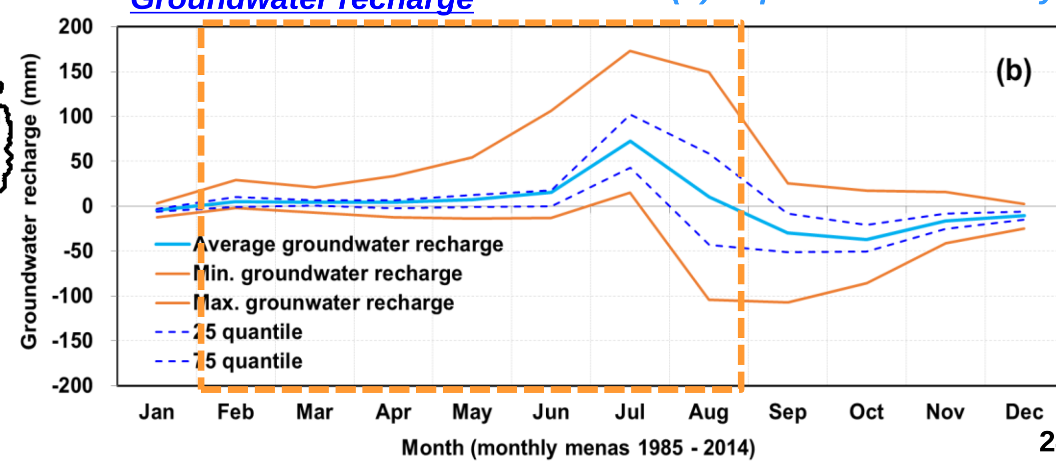
Impact of surface-groundwater exchange fluxes

Monthly average exchange fluxes (between surface water and groundwater) and groundwater recharge

- ✓ 30 years (1985-2014) simulated by SWAT







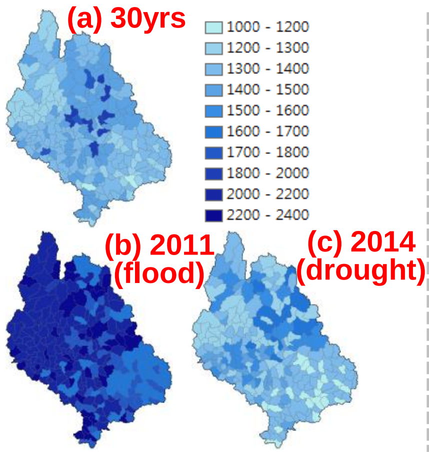
Watershed Soundness Assessment

Comparison of the water balance components

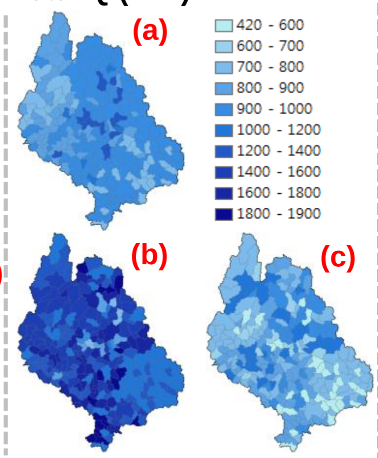
- ✓ 30 years (1985-2014), flood year (2011), drought year (2014)

Total

Precipitation (mm)

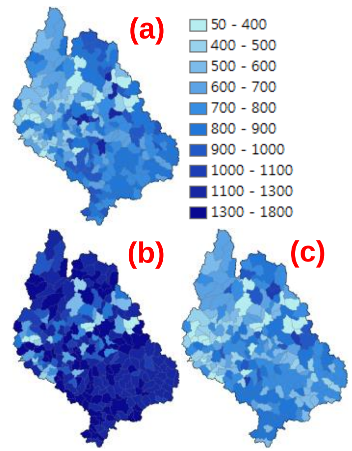


Total Q (mm)

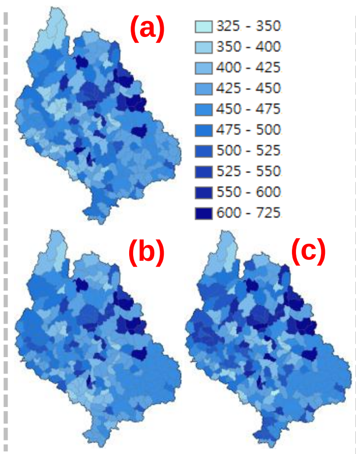


Surface Processes

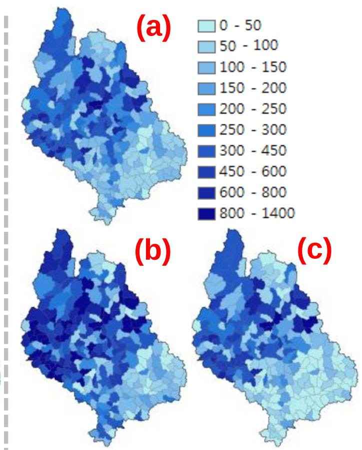
Infiltration (mm)



ET (mm)

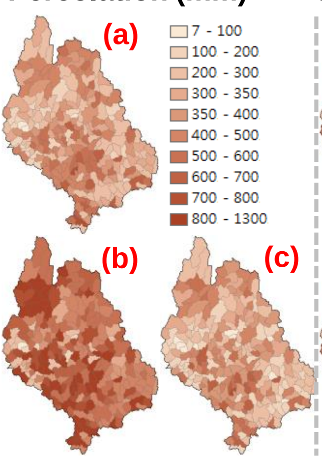


Surface runoff (mm)

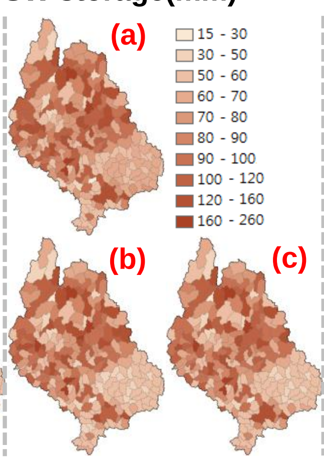


Soil Water Dynamics

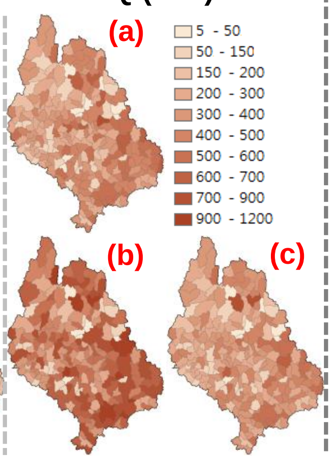
Percolation (mm)



SW storage(mm)

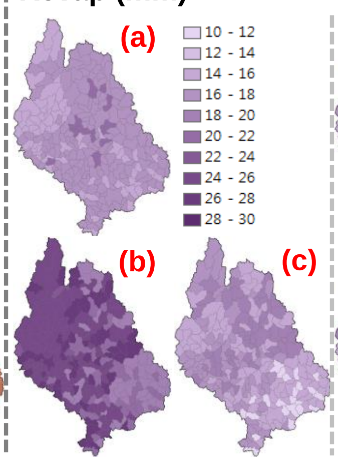


Lateral Q (mm)

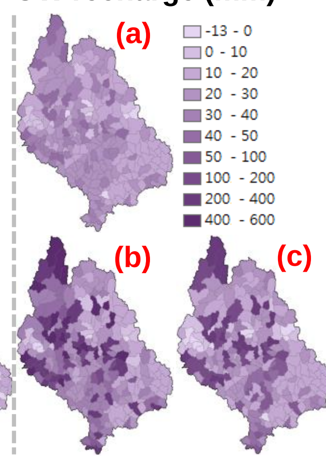


Groundwater Dynamics

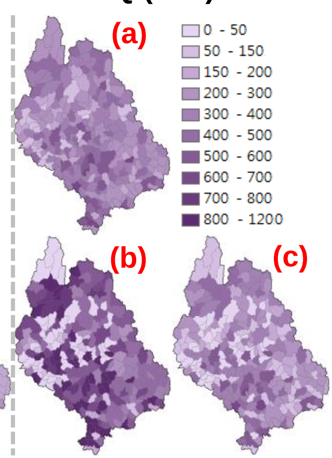
Revap (mm)



GW recharge (mm)



Return Q (mm)

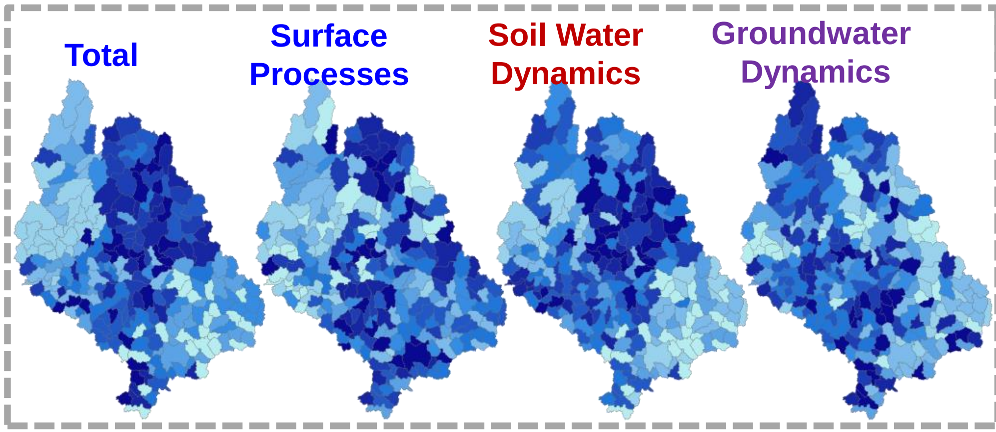


Watershed Soundness Assessment

Watershed soundness index (hydrology)

✓ 30 years (1985-2014)

Normalized sub-index



$$\text{Normalized component value} = \frac{\text{Simulated value for watershed x}}{\text{Max. value for all watersheds}}$$

↓

$$\text{Sub-index} = \frac{(\text{Normalized value 1} + \text{Normalized value 2} + \ldots + \text{Normalized value x})}{\text{Total number of normalized values}}$$

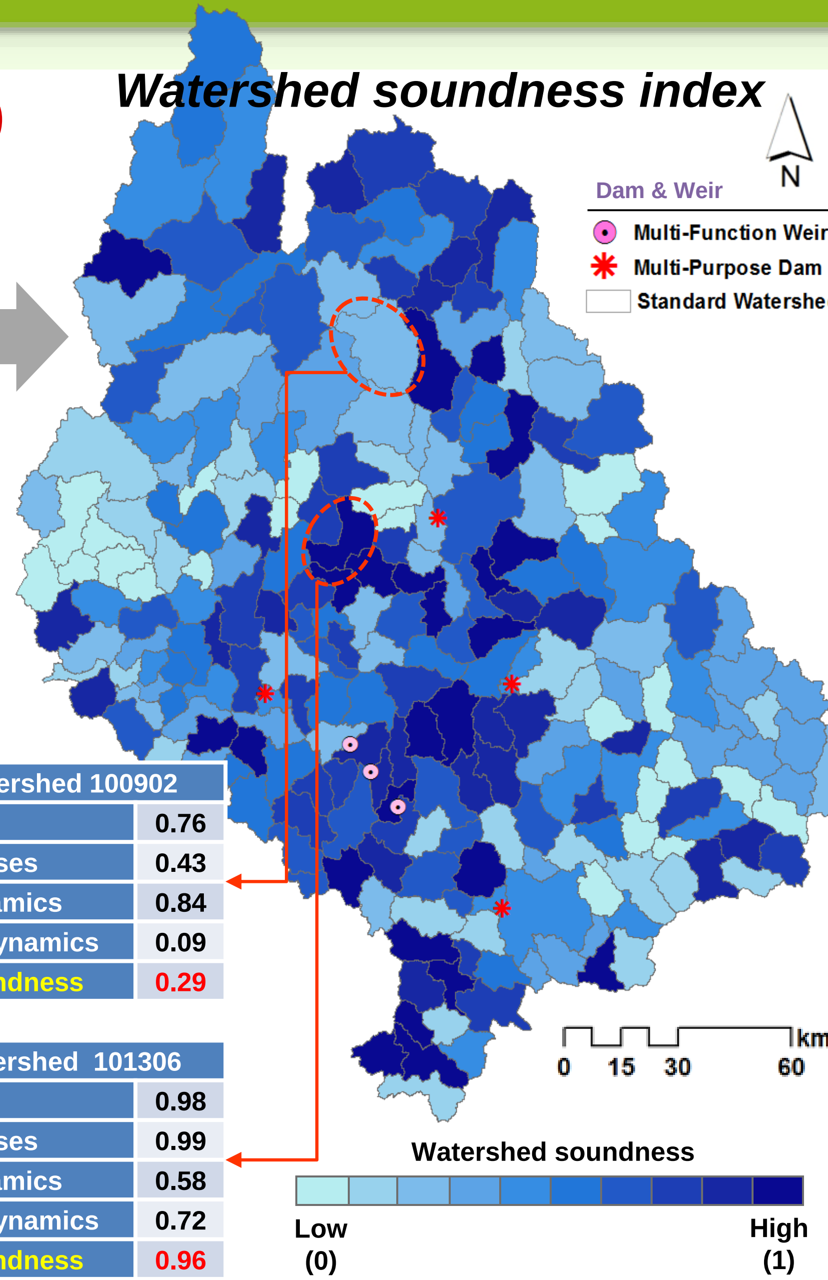
↓

$$\text{Watershed soundness index} = \frac{(\text{Sub-index 1} + \text{Sub-index 2} + \ldots + \text{Sub-index x})}{\text{Total number of sub-indices}}$$

Ref.) EPA 2012, Identifying and Protecting Healthy Watersheds

Standard watershed 100902	
Total	0.76
Surface Processes	0.43
Soil Water Dynamics	0.84
Groundwater Dynamics	0.09
Watershed soundness	0.29

Standard watershed 101306	
Total	0.98
Surface Processes	0.99
Soil Water Dynamics	0.58
Groundwater Dynamics	0.72
Watershed soundness	0.96



Summary and conclusions

- *In this study, the surface water and groundwater interaction modeling of Han River basin in South Korea was performed using SWAT model.*
  - ✓ *The SWAT was calibrated using 4 measured dam and 3 weir operation data (storage and inflow) and with spatial hydrologic component data (evapotranspiration and soil moisture).*
  - ✓ *The SWAT model was used in the analysis of the water balance by vertical water budget (INFILT, ET, PERCOL, SW, REVAP and GR) and the horizontal water transfers (SQ, LQ and RQ).*

- *During dry season (Oct. to May), the evapotranspiration and return flow was 29% and 10% higher compared to those of wet season. So, they should be treated as important factors for the whole hydrological cycle.*

- *The period of (a) February to August was characterized by net inflow of infiltration into the groundwater. For the (b) September to January period, the groundwater flow into the river of the basin showed net outflow. The whole period was nearly balanced by the net flux. The groundwater recharge was found as an important factor to show the same pattern of exchange fluxes during the hydrological year.*

- *The results of this research is planned to investigate the impact of climate and land use change scenarios on water resources and to assess the soundness and vulnerability of watershed regions.*

Thank you

Earth Information Engineering Lab.

Ahn, So Ra

Dept. of Civil and Environmental System Engineering

Konkuk University, Seoul, South Korea

Phone: +82-2-444-0186

Email: ahnsora@konkuk.ac,kr

Web: http://konkuk.ac.kr/~kimsj/