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Assessment of Agricultural Water Supply Capacity Using SWAT and MODSIM models

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Contents

- *Introduction (Why this study?)*
- *Research procedure*
- *Study area*
- *SWAT Model setup*
  - ✓ *Data for SWAT Model evaluation*
  - ✓ *Model Calibration and Validation*
- *MODSIM Model setup*
  - ✓ *Data for MODSIM Model evaluation*
  - ✓ *Agricultural water supply network*
- *Water balance analysis*
- *Assessment of impact on agricultural water supply capacity*
- *Summary & Concluding remarks*

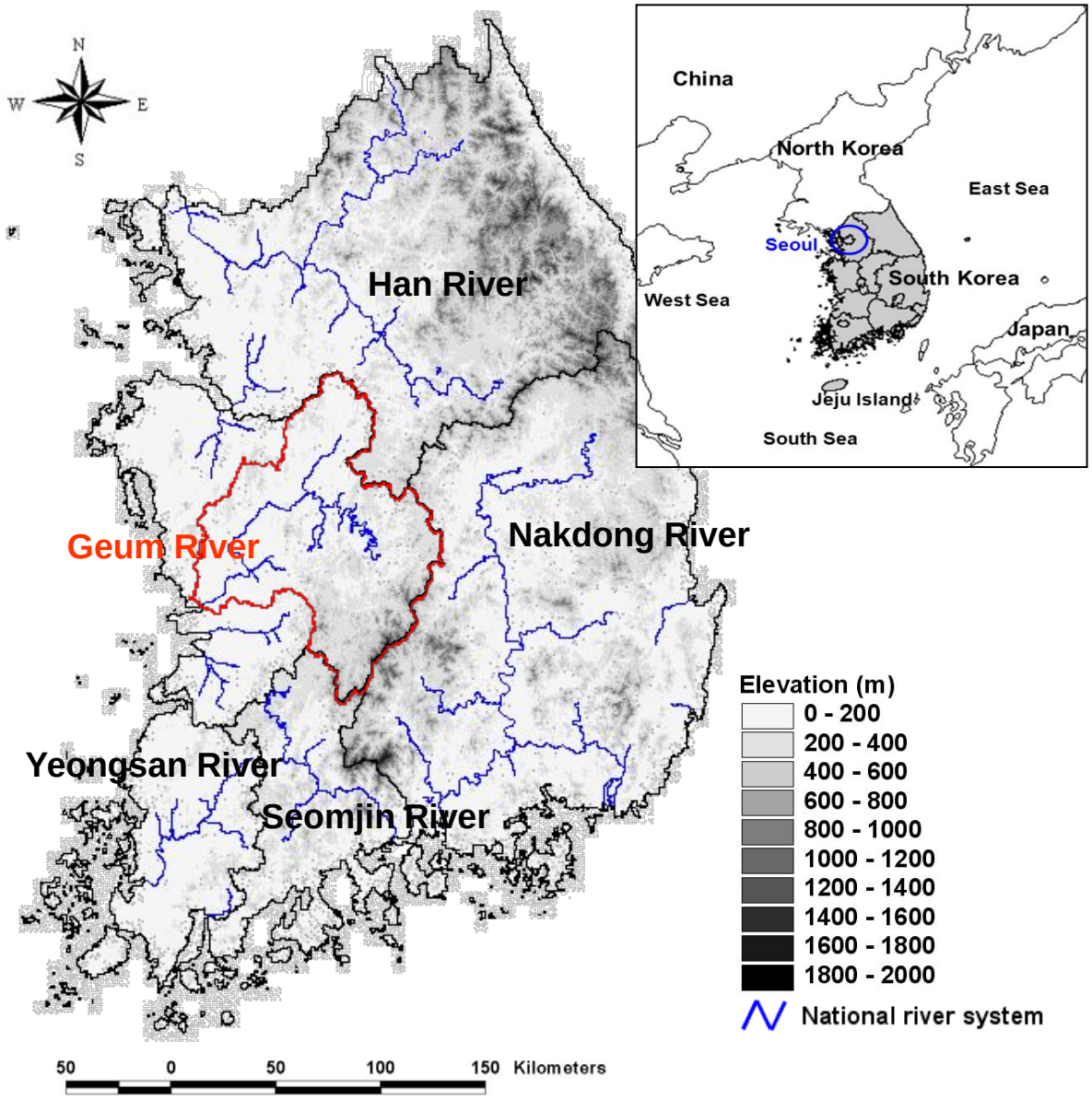
Introduction (Why this study?)

- ***The acute agricultural water shortage from drought is becoming a serious problem in South Korea where the water is of the essence from agriculture of mainly rice farming.***
  - ✓ ***The agricultural water shortage of irrigation per area in our country is considerably vulnerable to drought.***
  - ✓ ***It required a lot of efforts for securing agricultural water of irrigation facilities to flow from the water rich region into the water shortage region or store water in a reservoir to solve perennial problem of water shortage.***

- ***The assessment of the water shortage that is due to short supply according to water demand is obtained from water balance analysis.***

- ***The purpose of this study is to assess the agricultural water supply capacity for Geum River basin, where includes 2 multipurpose dams of South Korea using SWAT and MODSIM models.***

5 River Basins of South Korea



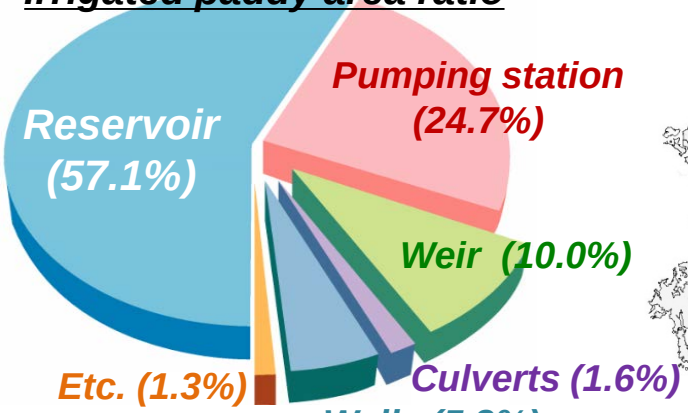
- ***5 River basins in our country (Han, Geum, Yeongsan, Seomjin and Nakdong)***
- ***The global warming is now warning the management of streamflow (intensify drought and flood)***
- ***Need to evaluate the water supply capacity by water balance analysis***
- ***From the evaluation, find out some insight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

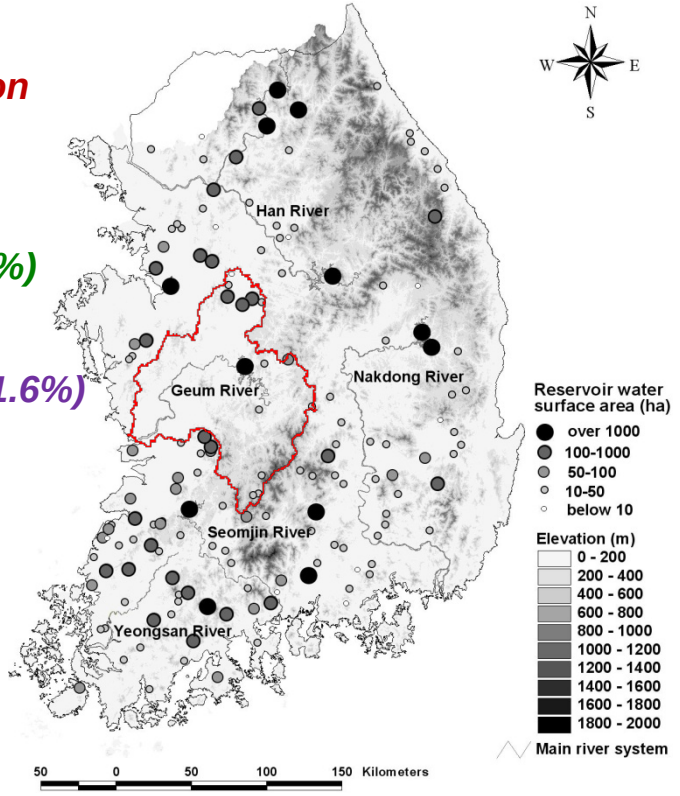
Agricultural Irrigation Facilities of South Korea

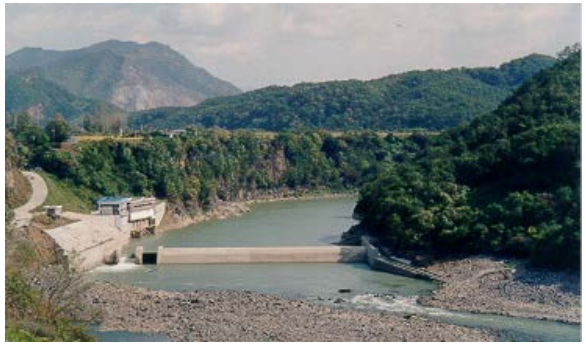
- ***A total of 67,582 irrigation facilities (reservoirs, pumping stations, diversion weirs, culverts, groundwater wells) in South Korea are being managed by both Korea Rural Community Corporation and local governments.***

Reservoir

Irrigated paddy area ratio



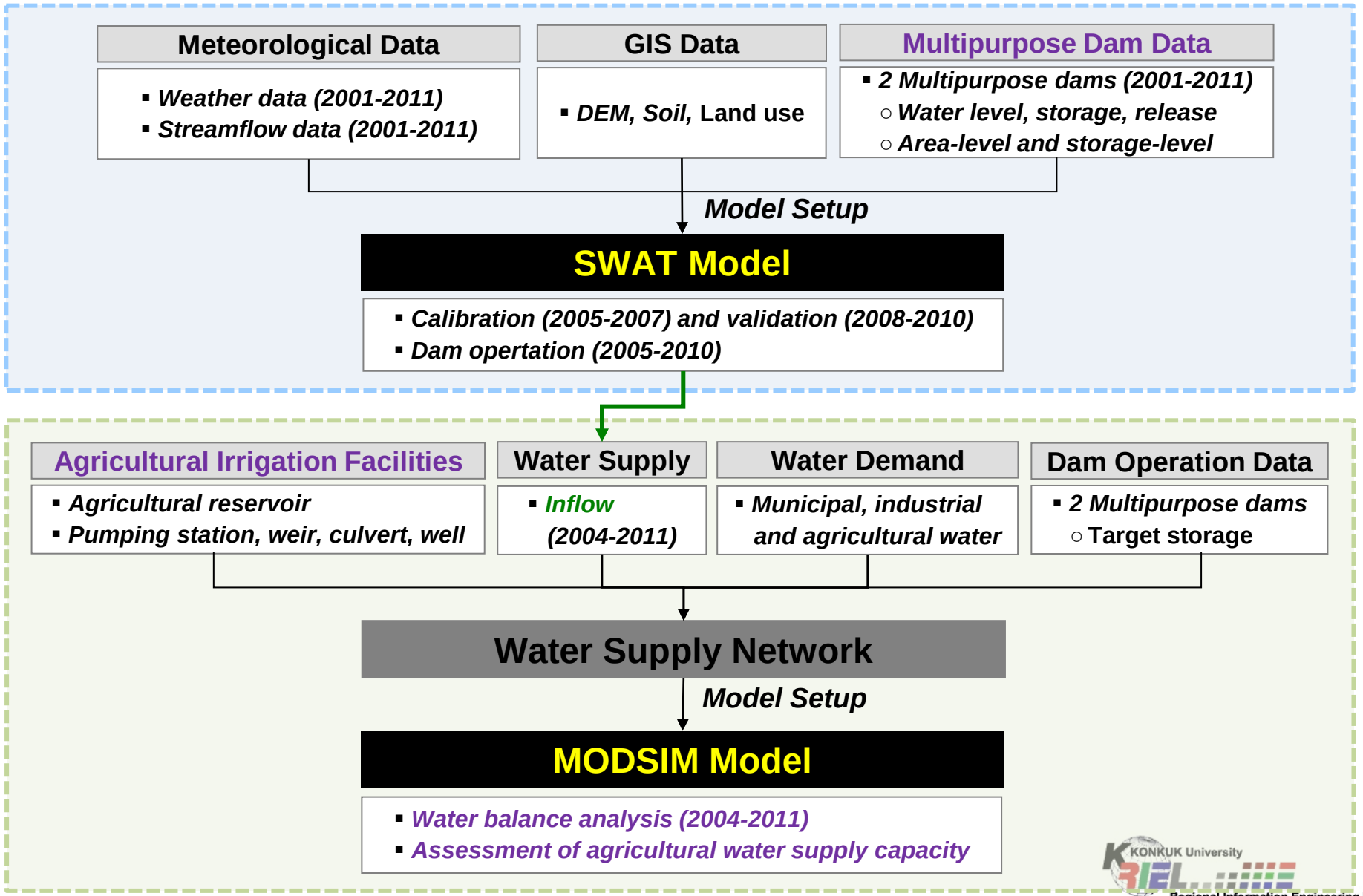




Pumping station

Diversion weir

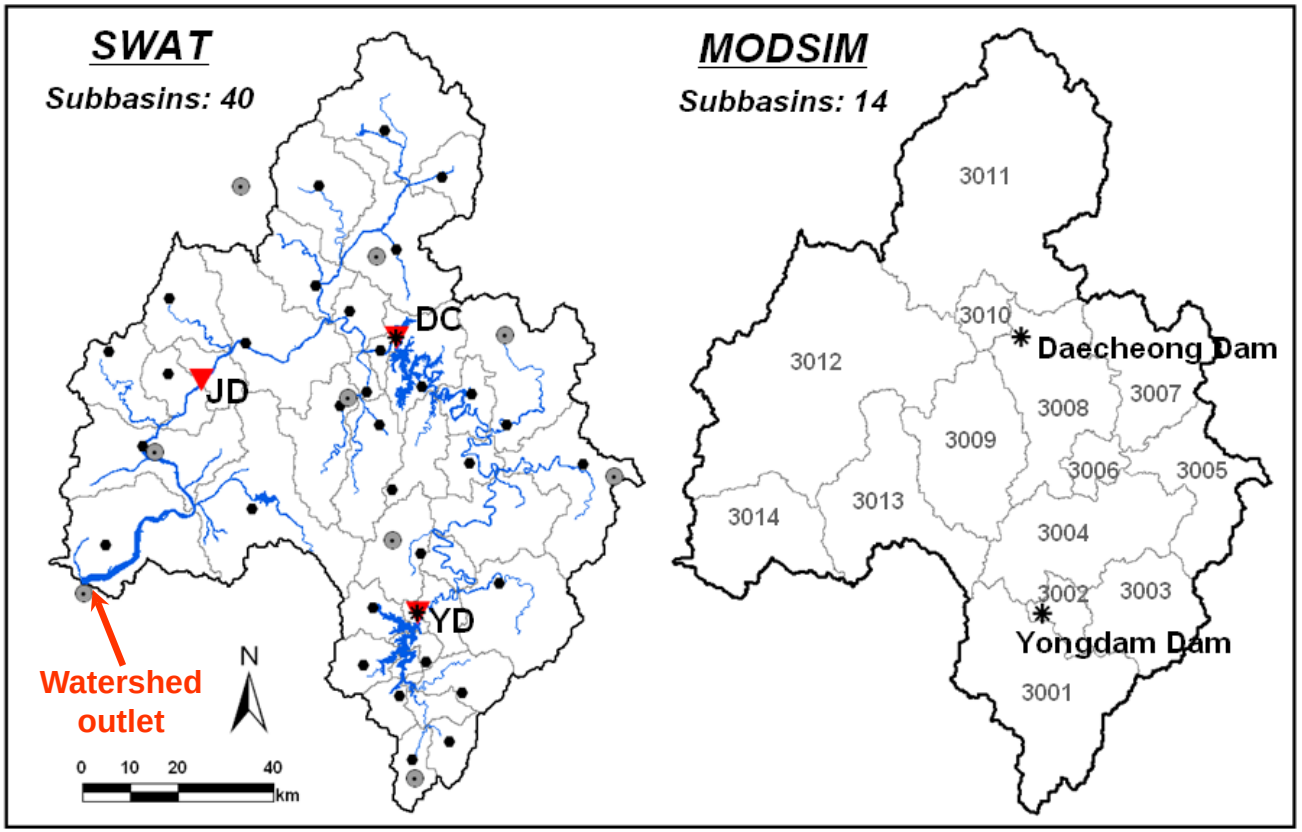
Research Procedure



Study Area

Legend

- Multipurpose Dam
- Water Level Station
- Weather Station
- Rainfall Station
- Stream
- Basin Boundary
- Subbasins Boundary



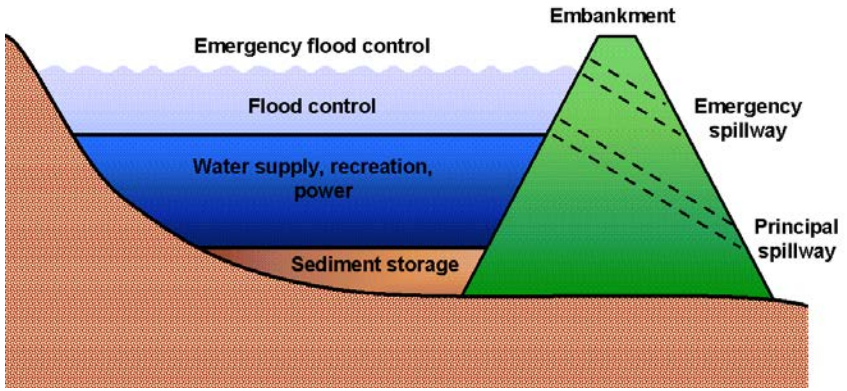
- *Third largest river of five rivers (Han, Nakdong, Geum, Yeongsan, Seomjin) in South Korea*
- *Geum River basin (9645.5 km²)*
  - ✓ *Average precipitation 1323.1 mm*
  - ✓ *Average temperature 12.2℃*

SWAT Model

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

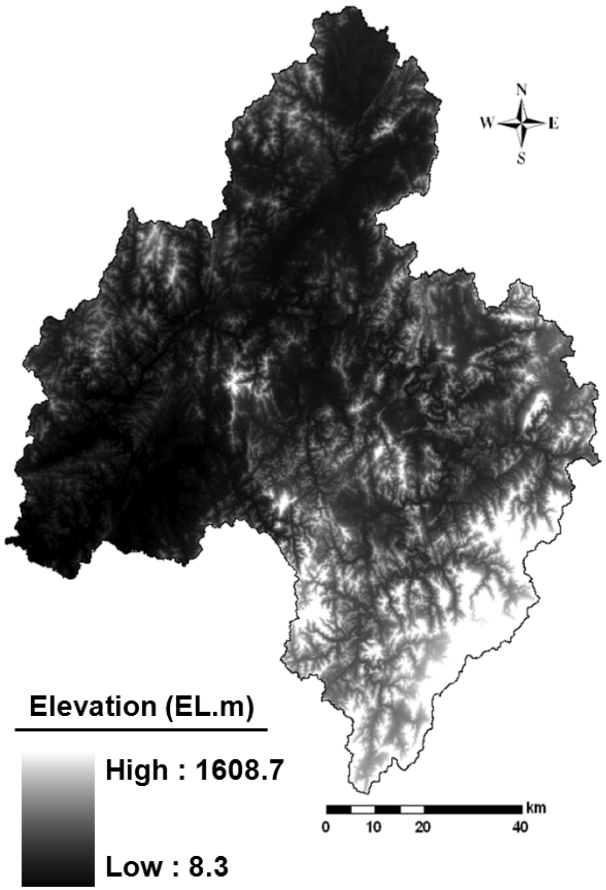
$$V = V_{stored} + V_{flowin} - V_{flwout} + V_{pcp} - V_{evap} - V_{seep}$$

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).

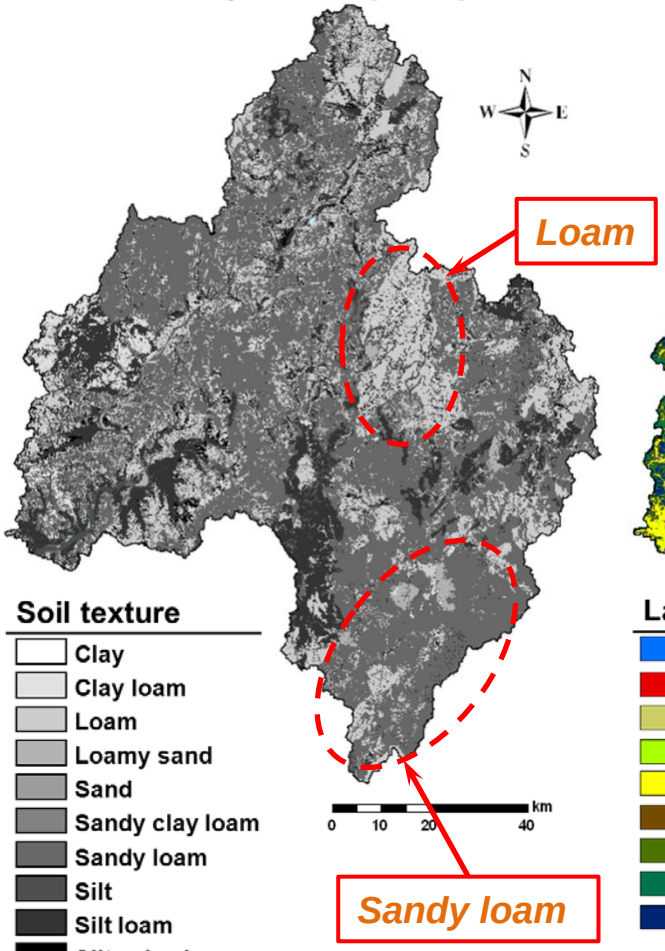
Data for SWAT Model evaluation

GIS data

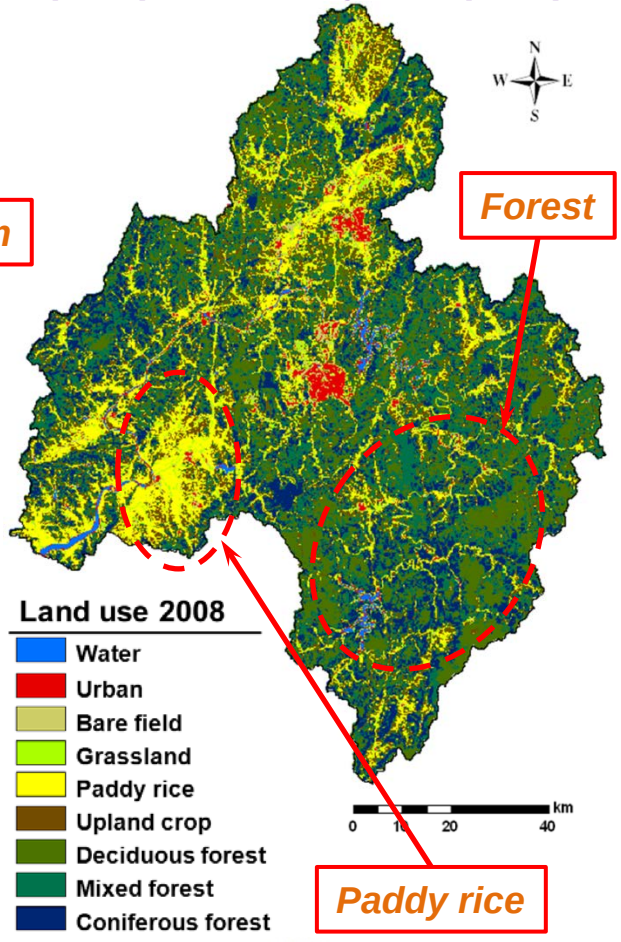
Elevation : 8 - 1609m (average: 224.3m)



Soil : Loam (24%) and sandy loam (58%)

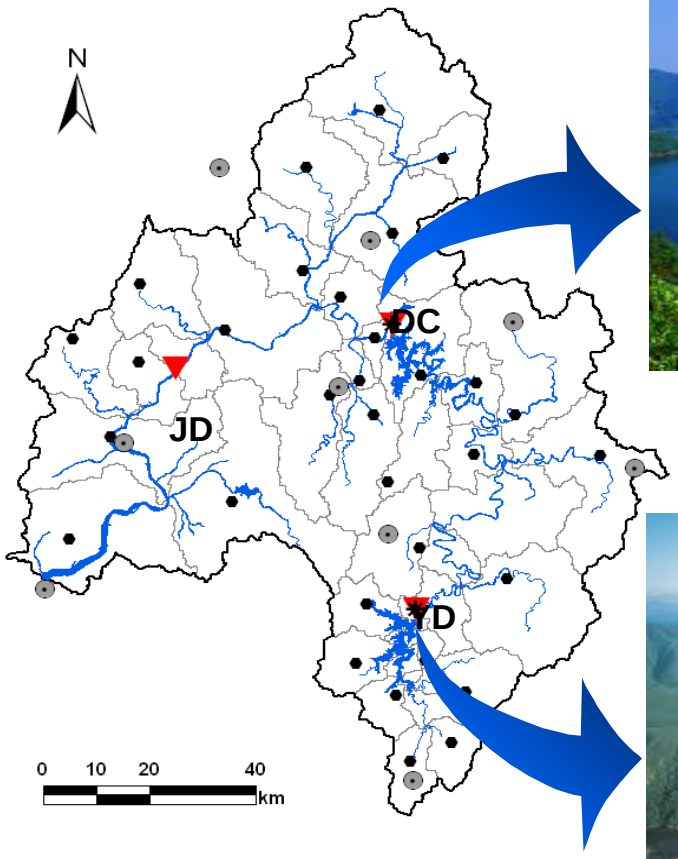


Land cover (2008) : Forest (62%) and Paddy rice (15%)



Data for SWAT Model evaluation

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

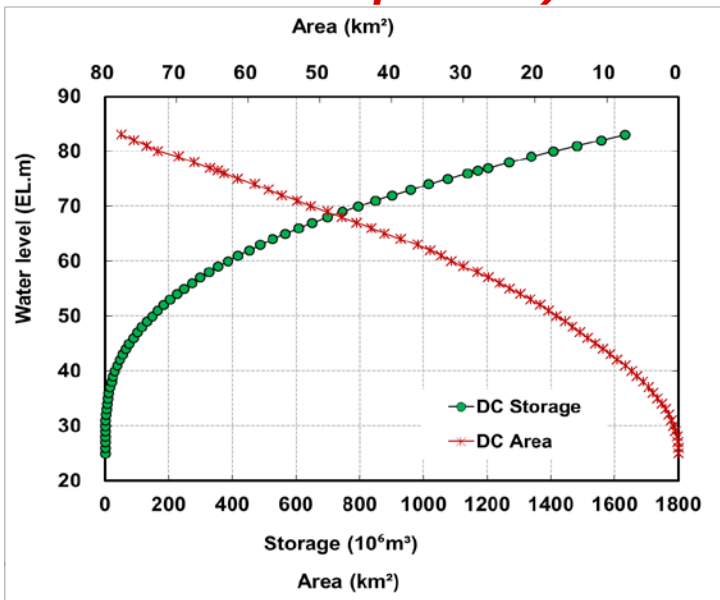


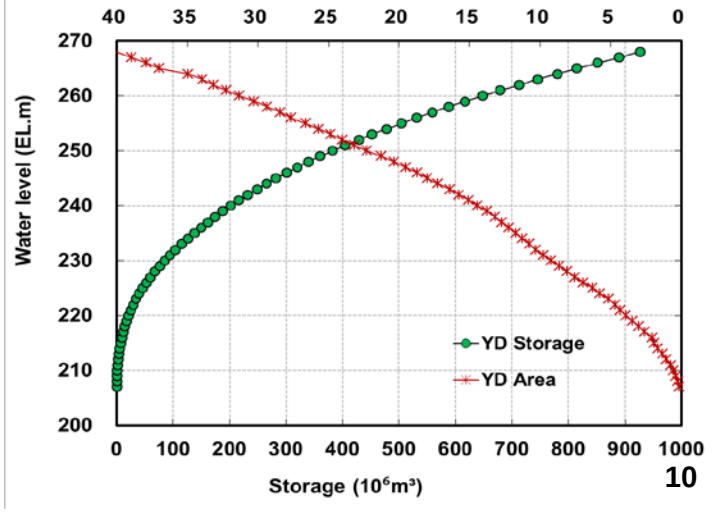
Daecheong dam (DC)

- ✓ *Total storage : 1,490 m³*
- ✓ *Area : 3,204 m³*

Yongdam dam (YD)

- ✓ *Total storage : 815 m³*
- ✓ *Area : 930 m³*

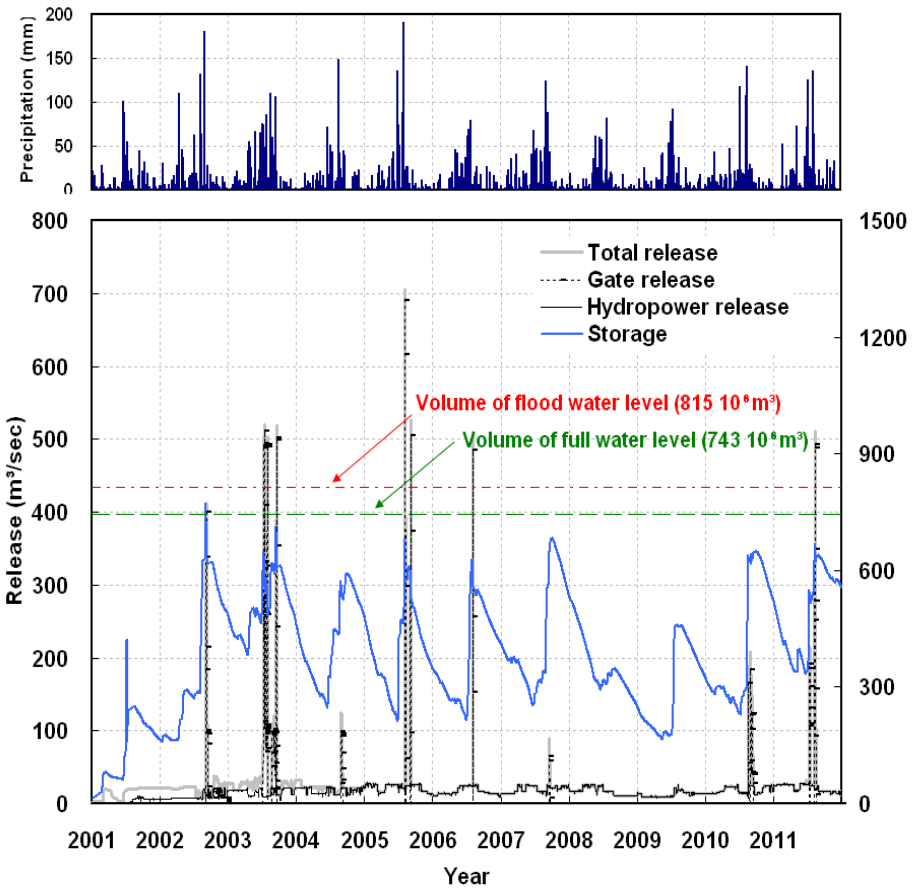




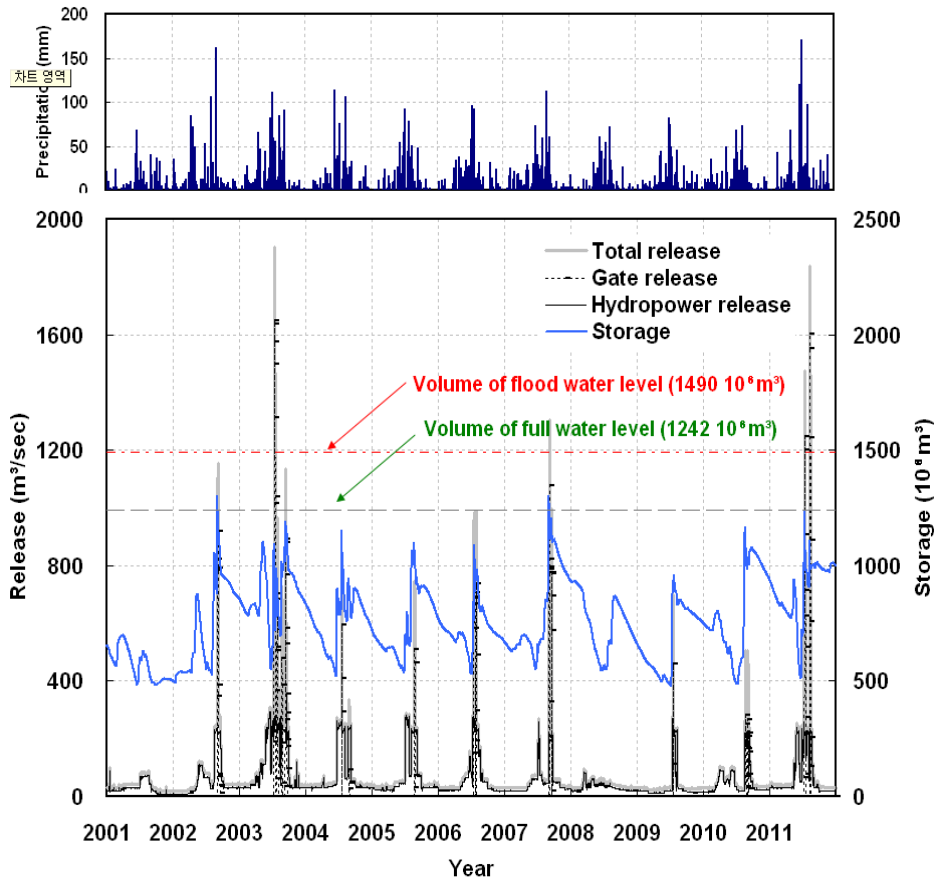
Data for SWAT Model evaluation

2 Multipurpose dam data (release and storage : 2001-2011)

Yongdam dam (YD)



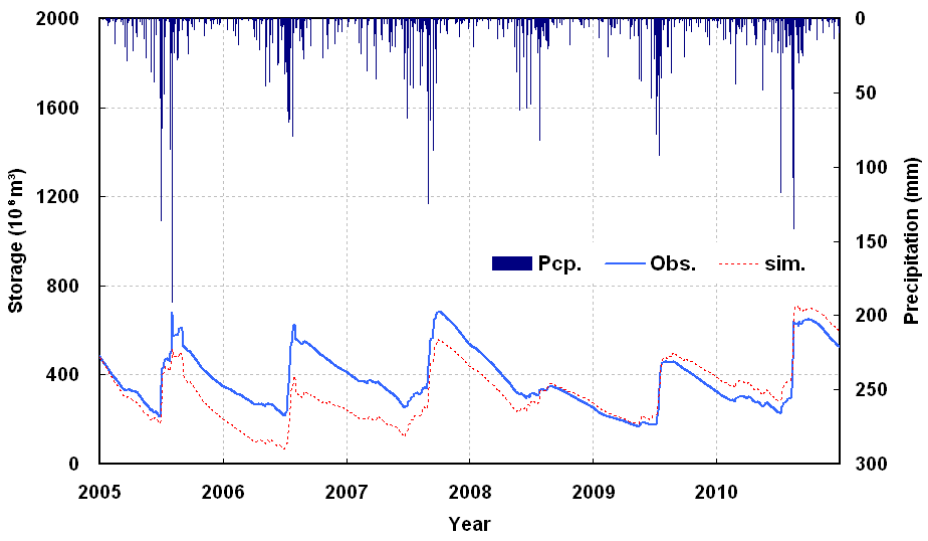
Daecheong dam (DC)



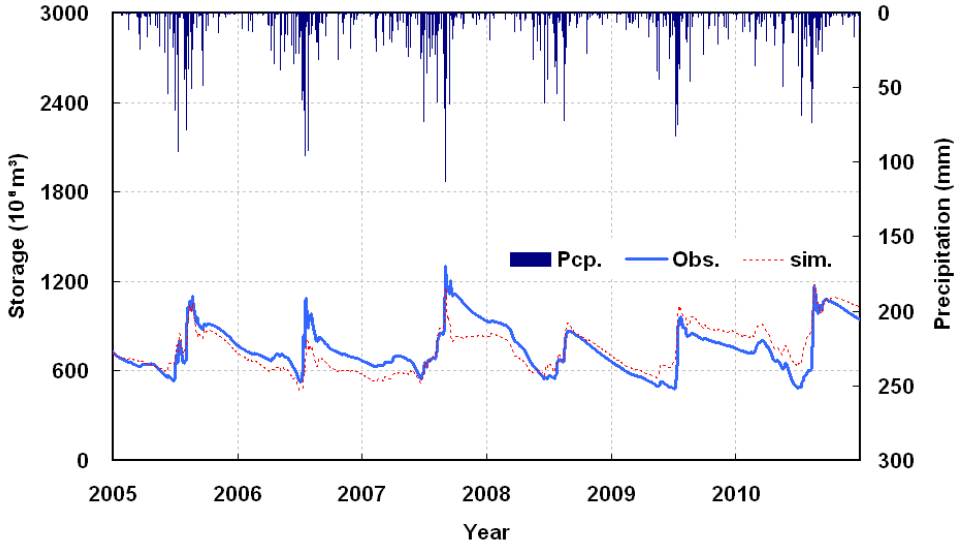
Model calibration and validation

Fitted results of 2 dams storage and input parameters

Yongdam dam (YD)



Daecheong dam (DC)

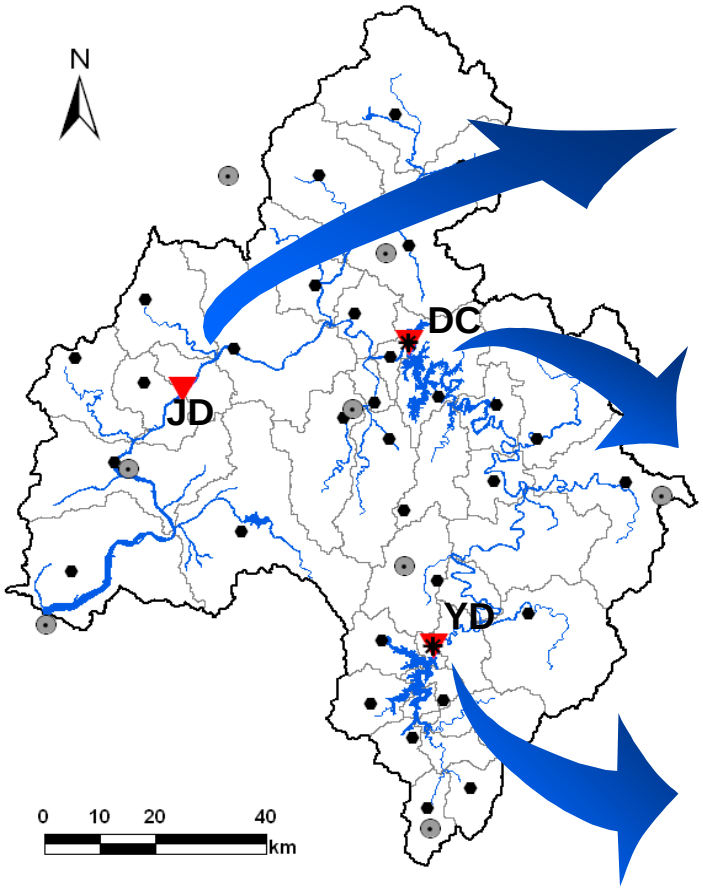


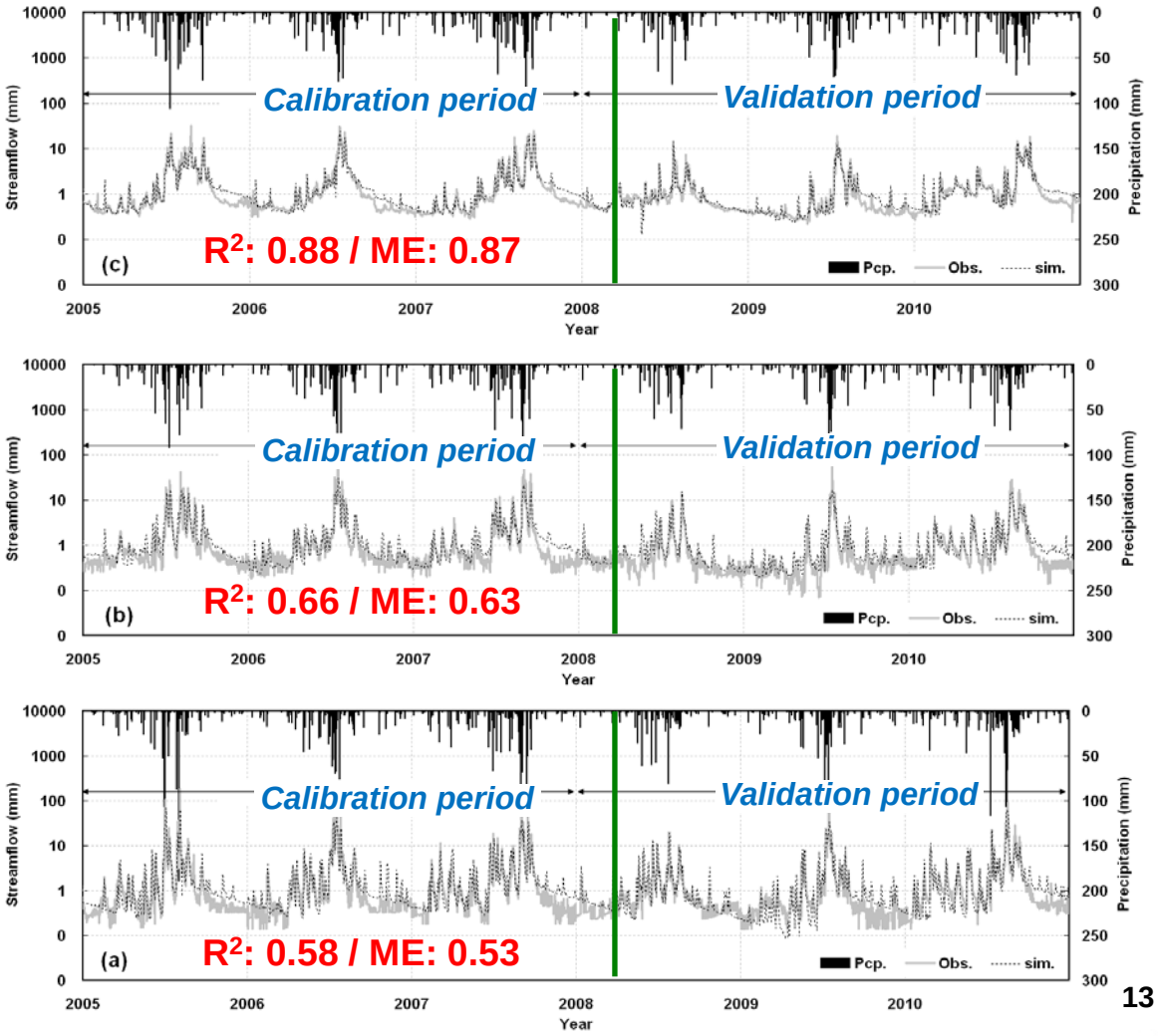
Parameters	Definition	Multipurpose Dams	
		YD	DC
IYRES	Year the reservoir became operational	2005	2005
RES_ESA	Reservoir surface area when the reservoir is filled to the emergency spillway (km²)	37.0	74.2
RES_EVOL	Volume of water needed to fill the reservoir to the emergency spillway (10^6m³)	815.0	1490.0
RES_PSA	Reservoir surface area when the reservoir is filled to the principal spillway (km²)	33.9	67.5
RES_PVOL	Volume of water needed to fill the reservoir to the principal spillway (10^6m³)	742.5	1241.6
RES_VOL	Initial reservoir volume (10^6m³)	479.5	722.8
RES_K	Hydraulic conductivity of the reservoir bottom (mm/hr)	0.5	0.1

Model calibration and validation

Observed vs. simulated streamflow results of model calibration and validation

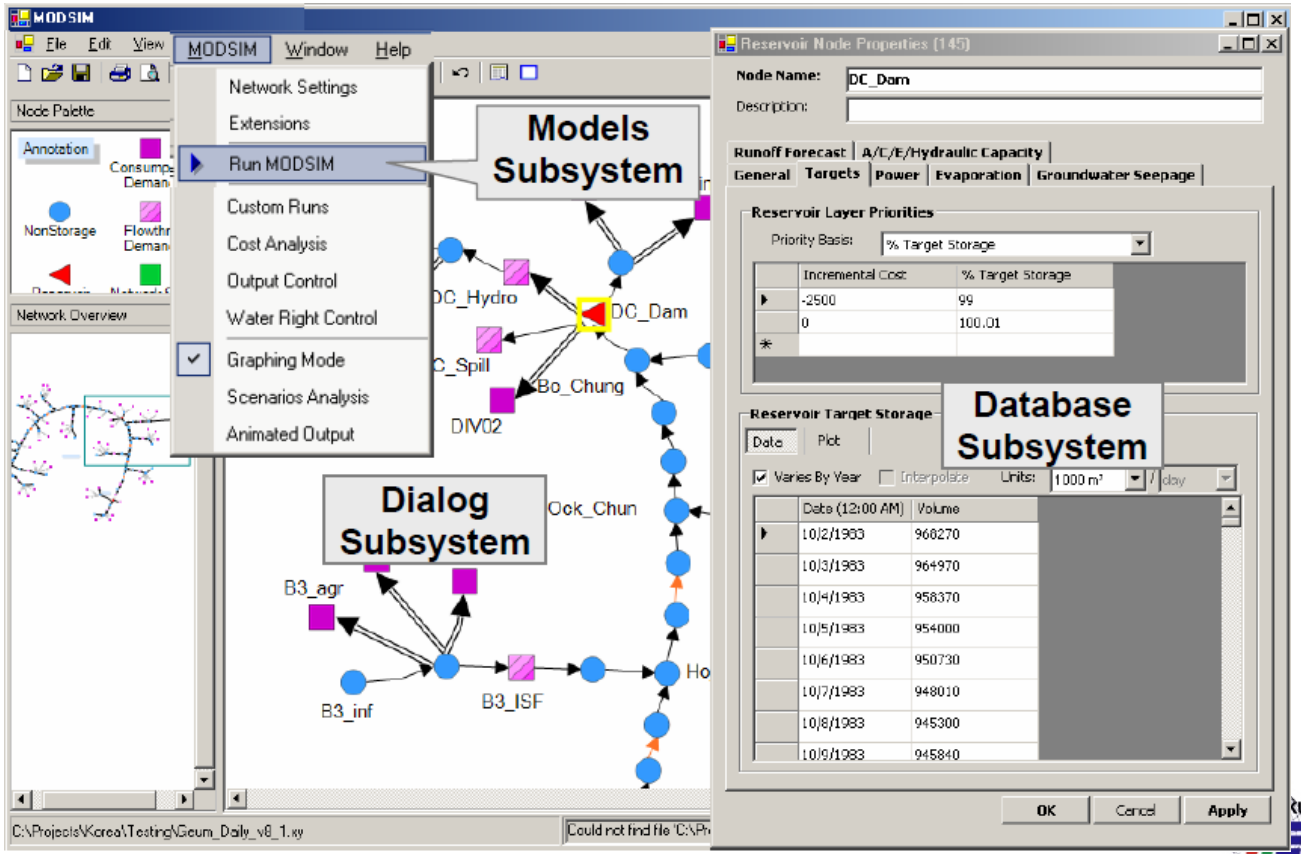
✓ **Calibration :** 3 years (2001-2003) / **Validation :** 3 years (2004-2006)





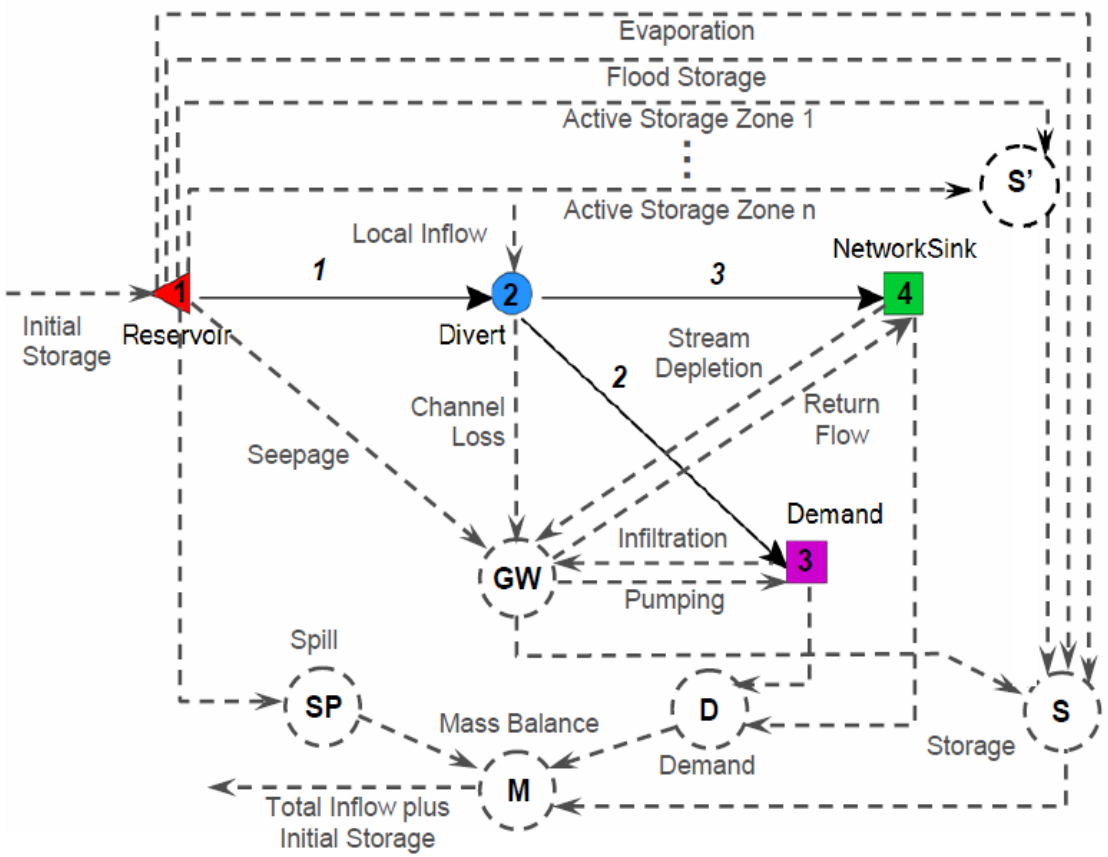
MODSIM Model

- ***MODSIM - DSS : a generalized river basin Decision Support System and network flow model developed at Colorado State University designed specifically to meet the growing demands and pressures on river basin management***
- ***Reservoir operation, watershed management and drought management planning***



MODSIM Model

MODSIM network structure with artificial nodes and links

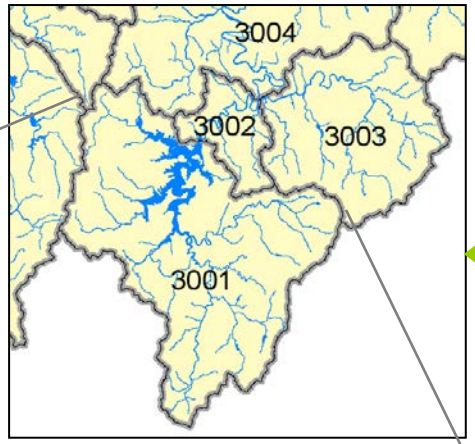


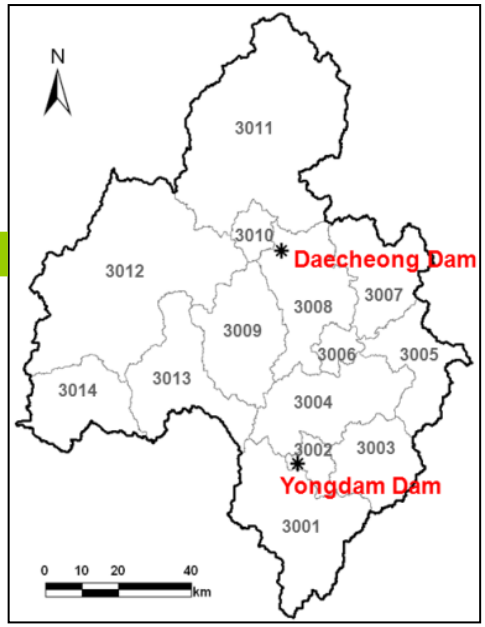
Icon	Functionality
Reservoir [Operations]	▪ Main-stream reservoir operation
NonStorage	▪ Watershed runoff ▪ Tributary inflow
Demand	▪ Consumptive demand
Flowthru	▪ Nonconsumptive demand
NetworkSink	▪ River basin outlet
Link	▪ Channel losses

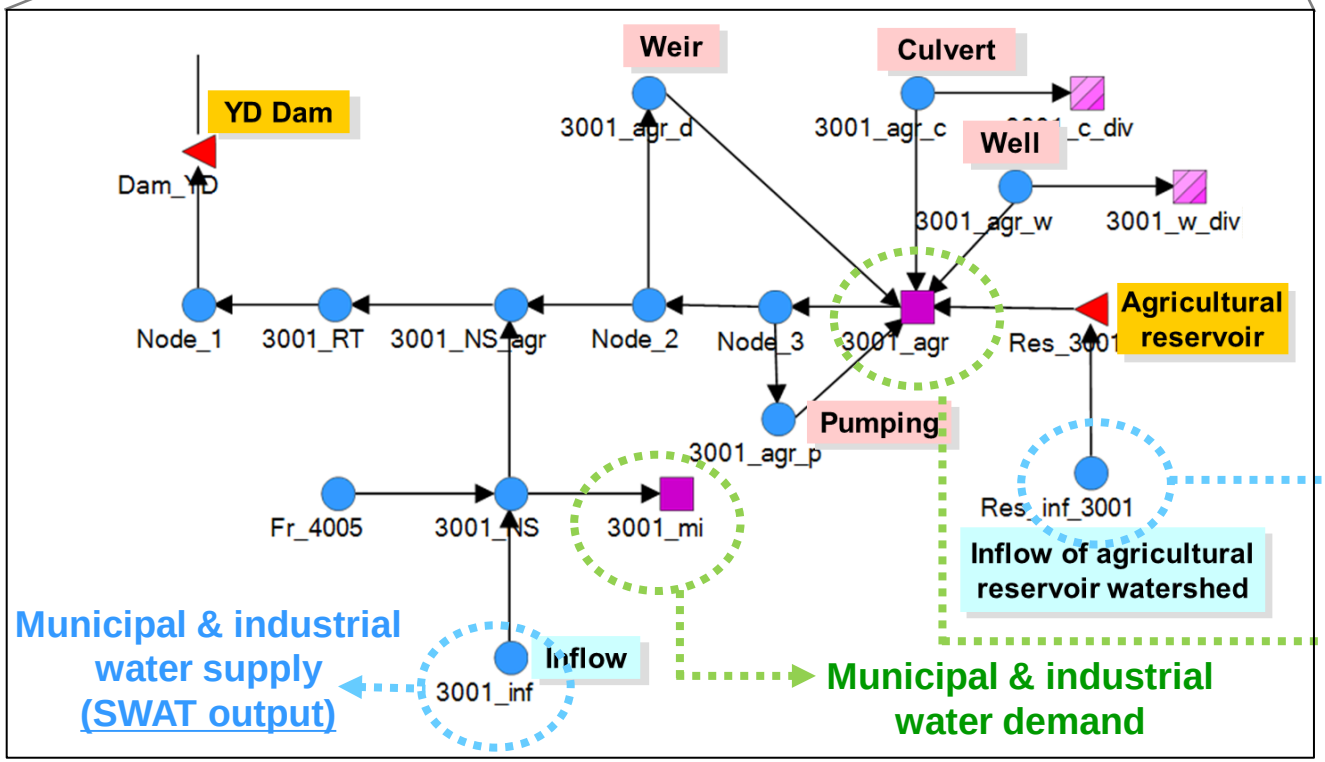
Agricultural water supply network

Agricultural irrigation facilities

- ✓ Agricultural reservoirs
- ✓ Pumping stations
- ✓ Diversion weirs
- ✓ Culverts
- ✓ Groundwater wells







Agricultural water supply (SWAT output)

Municipal & industrial water supply (SWAT output)

Agricultural water demand

Municipal & industrial water demand

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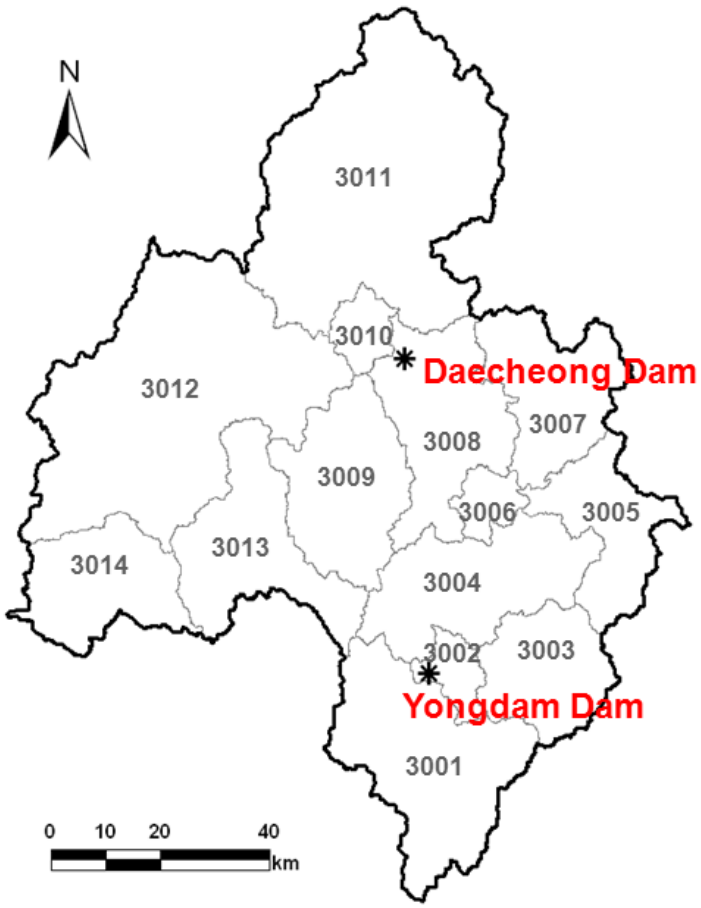
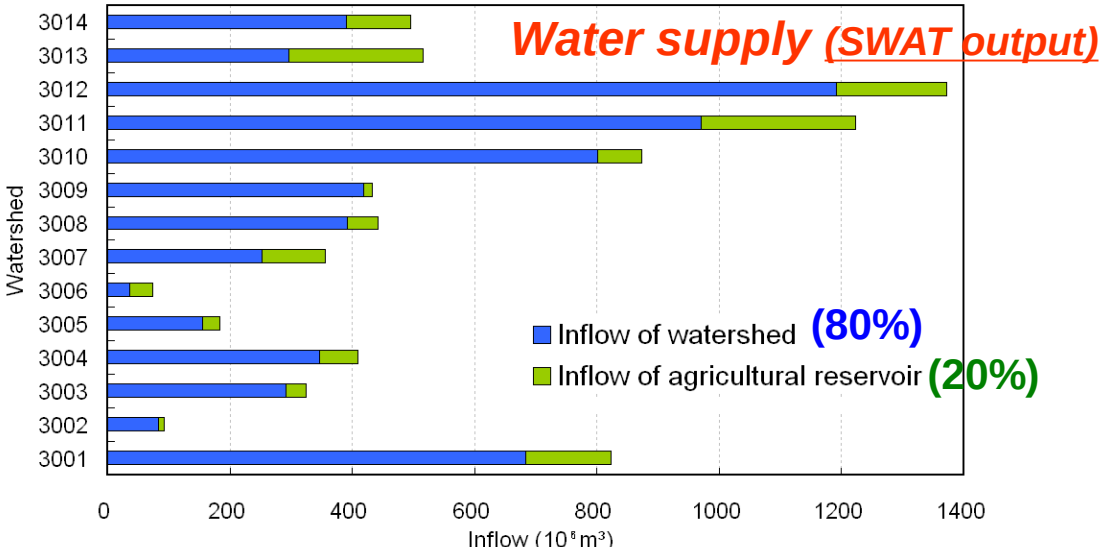
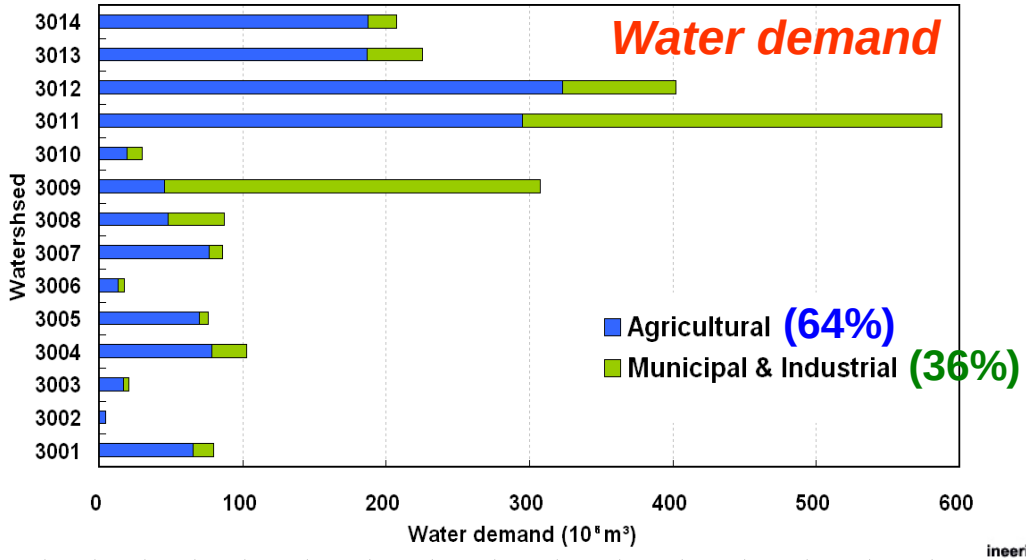
Data for MODSIM Model evaluation

Water supply (Inflow) and water demand (Municipal, industrial and agricultural water)



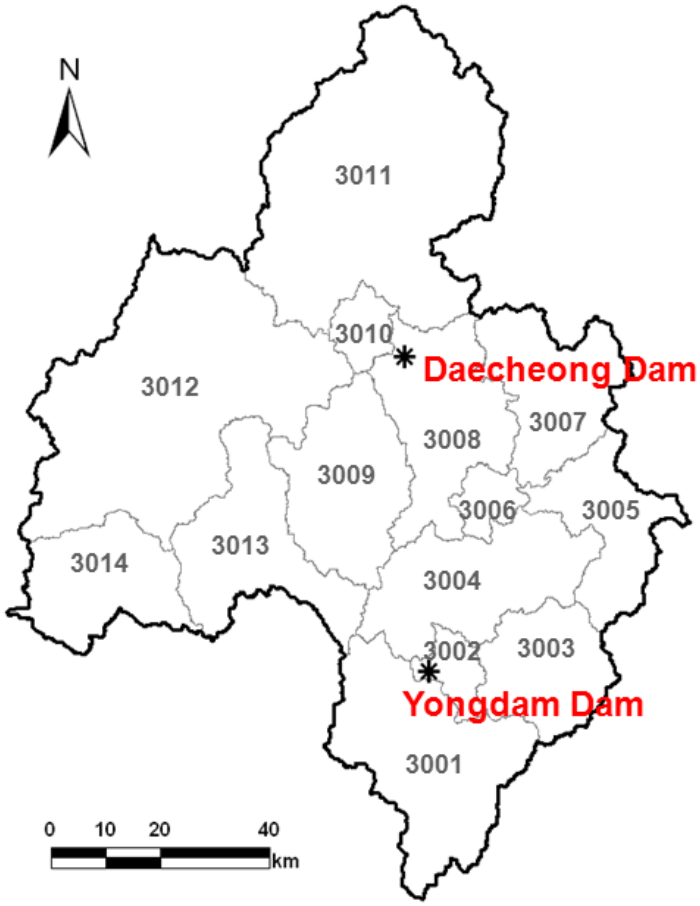


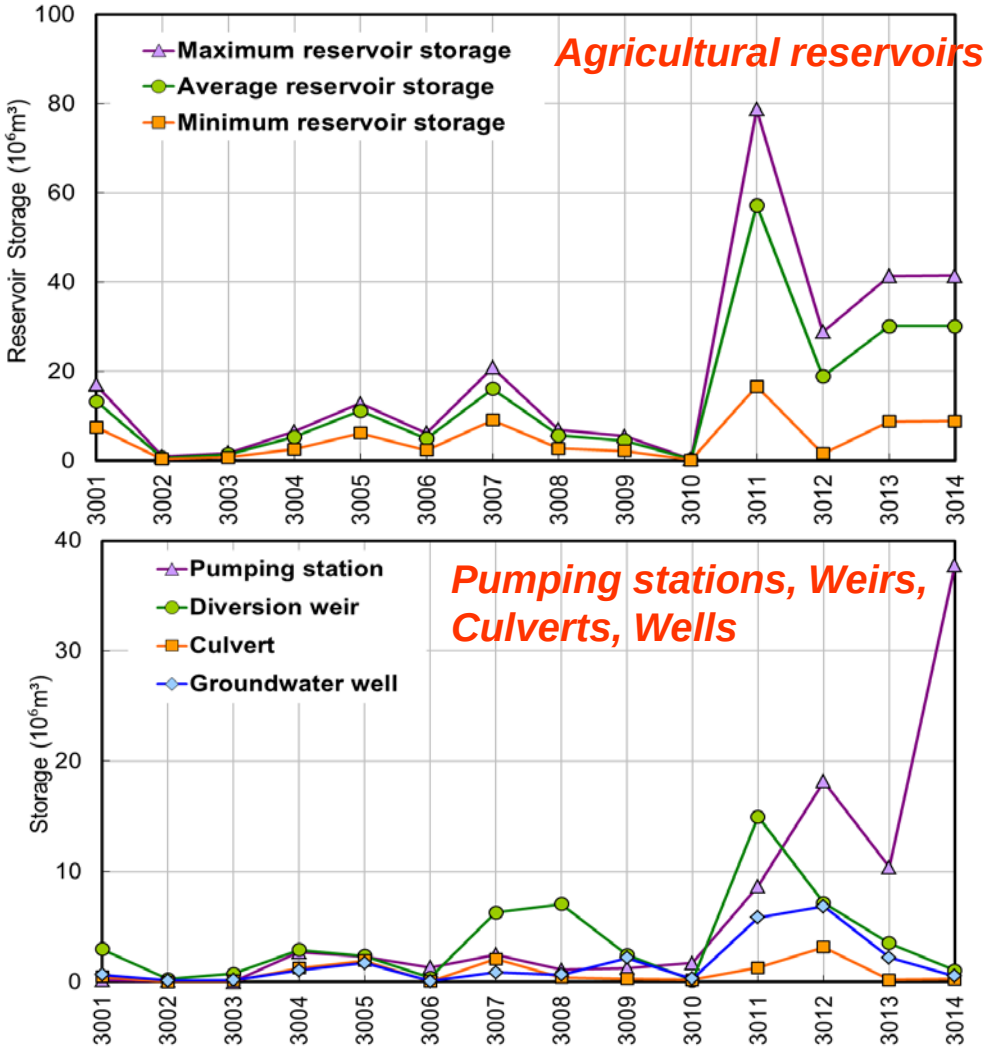


Data for MODSIM Model evaluation

Agricultural irrigation facilities

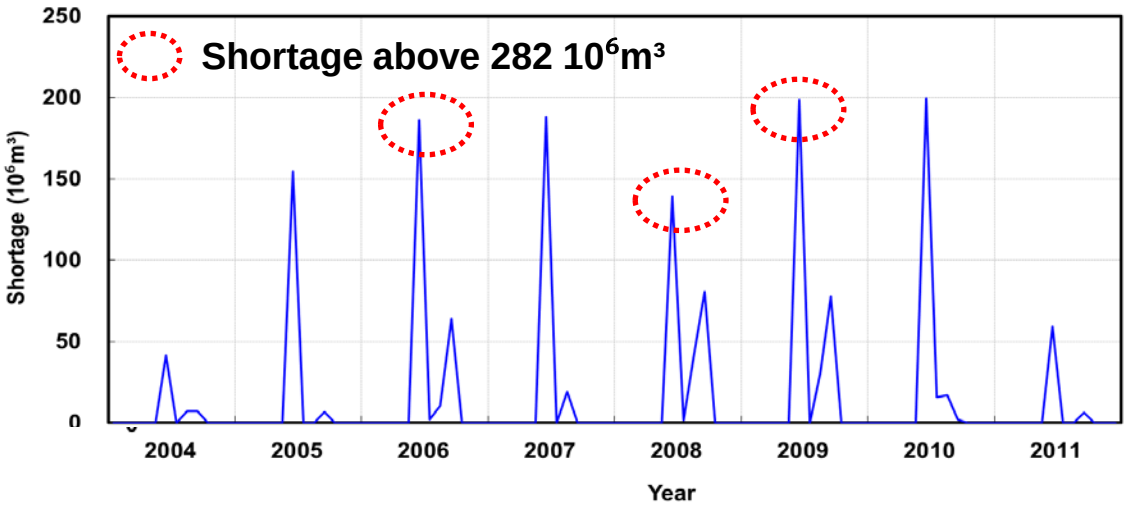
✓ Agricultural reservoirs, Pumping stations, Weirs, Culverts, Wells





Water balance analysis

Year	Municipal and industrial water					Agricultural water				
	Demand ($10^6 m^3$)	Supply (10^6 m^3)	Potential water supply rate (%)	Shortage (10^6 m^3)	Shortage rate (%)	Demand (10^6 m^3)	Supply (10^6 m^3)	Potential water supply rate (%)	Shortage (10^6 m^3)	Shortage rate (%)
2004	872.0	870.4	99.8	1.6	0.2	1530.8	1470.7	96.1	60.1	3.9
2005	872.0	865.7	99.3	6.3	0.7	1530.8	1357.5	88.7	173.3	11.3
2006	872.0	865.7	99.3	6.3	0.7	1530.8	1248.8	81.6	282.0	18.4
2007	872.0	870.7	99.8	1.3	0.2	1530.8	1308.6	85.5	222.2	14.5
2008	872.0	863.9	99.1	8.1	0.9	1530.8	1247.8	81.5	283.0	18.5
2009	872.0	856.2	98.2	15.8	1.8	1530.8	1201.7	78.5	329.1	21.5
2010	872.0	871.8	100.0	0.2	0.0	1530.8	1279.1	83.6	251.7	16.4
2011	872.0	871.3	99.9	0.8	0.1	1530.8	1460.7	95.4	70.1	4.6

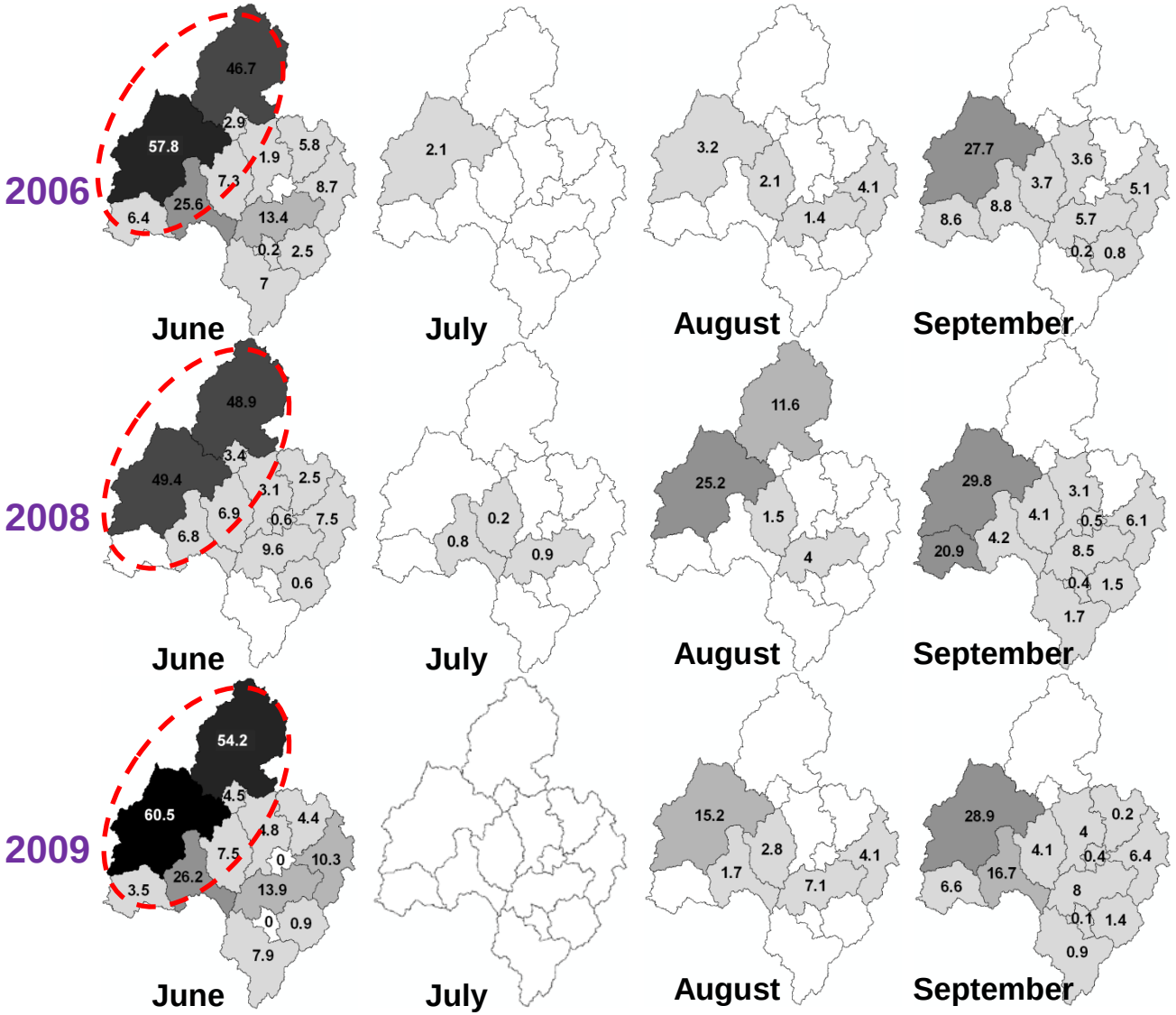


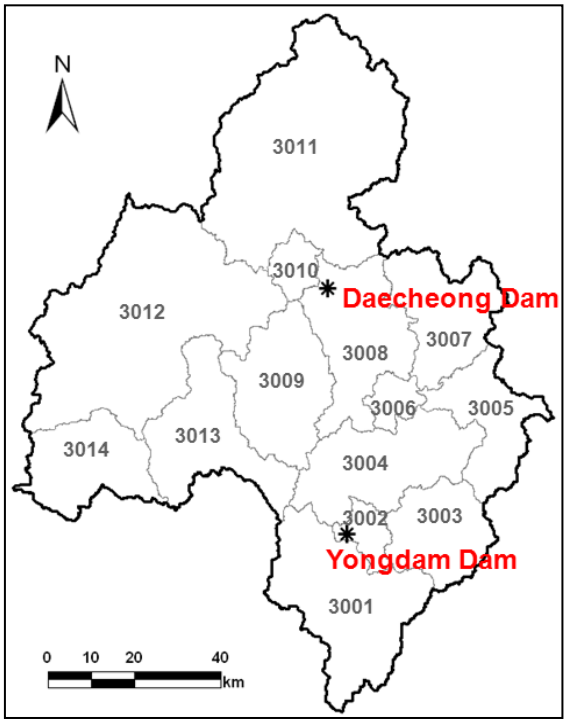
Water balance analysis

Watershed	Municipal and industrial water					Agricultural water				
	Demand (10^6m^3)	Supply (10^6m^3)	Potential water supply rate (%)	Shortage (10^6m^3)	Shortage rate (%)	Demand (10^6m^3)	Supply (10^6m^3)	Potential water supply rate (%)	Shortage (10^6m^3)	Shortage rate (%)
3001	15.0	15.0	100.0	0.0	0.0	65.2	60.6	92.9	4.6	7.1
3002	0.7	0.7	100.0	0.0	0.0	4.5	4.3	95.7	0.2	4.3
3003	4.1	3.6	88.4	0.5	11.6	17.0	15.1	89.3	1.8	10.7
3004	25.2	25.2	100.0	0.0	0.0	78.2	63.8	81.6	14.3	18.4
3005	7.0	6.4	92.5	0.5	7.5	69.8	57.3	82.2	12.5	17.8
3006	5.0	5.0	100.0	0.0	0.0	13.1	12.9	98.6	0.2	1.4
3007	10.3	10.2	99.3	0.1	0.7	76.5	73.2	95.6	3.3	4.4
3008	40.3	40.3	100.0	0.0	0.0	47.7	44.2	92.7	3.5	7.3
3009	262.6	262.6	100.0	0.0	0.0	45.8	35.9	78.3	10.0	21.7
3010	11.2	11.2	100.0	0.0	0.0	19.2	16.8	87.6	2.4	12.4
3011	293.3	289.8	98.8	3.5	1.2	294.8	254.7	86.4	40.1	13.6
3012	79.8	79.8	100.0	0.0	0.0	323.2	249.9	77.3	73.3	22.7
3013	39.1	39.0	99.7	0.1	0.3	186.6	166.2	89.1	20.4	10.9
3014	20.4	20.4	100.0	0.0	0.0	187.2	178.8	95.5	8.4	4.5
Total	813.9	809.2	98.5	4.7	1.5	1428.8	1233.7	88.8	195.0	11.2

Assessment of impact on agricultural water supply capacity

Agricultural water shortage in drought period (2006, 2008, 2009)





Agricultural Shortage ($10^6 m^3$)

- No shortage
- 1 – 10
- 10 – 20
- 20 – 30
- 30 – 40
- 40 – 50
- 50 – 60
- Above 60

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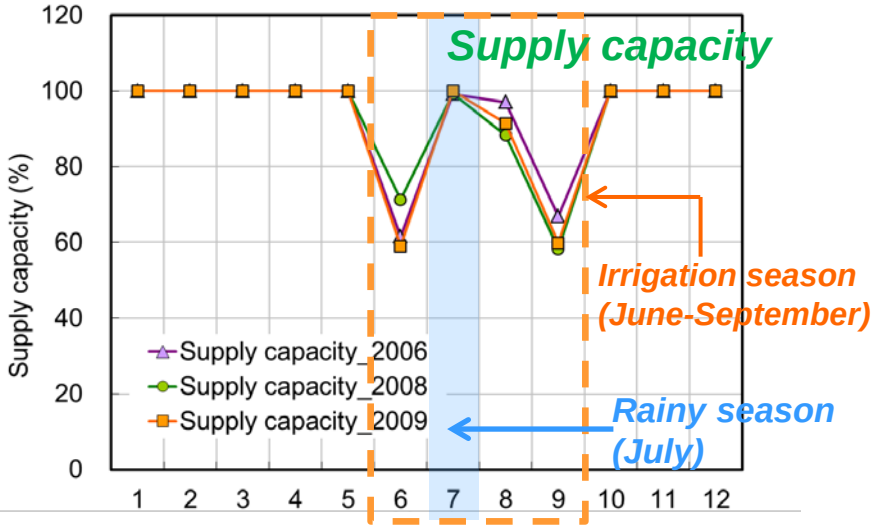
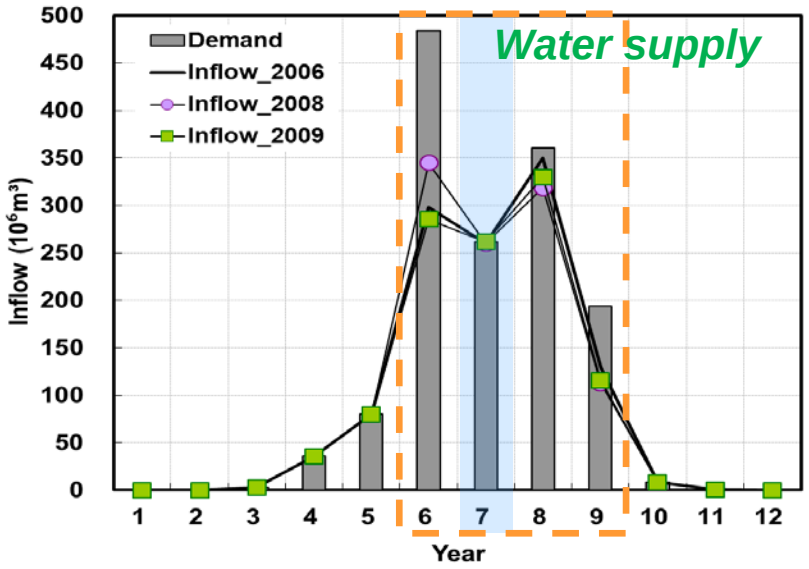
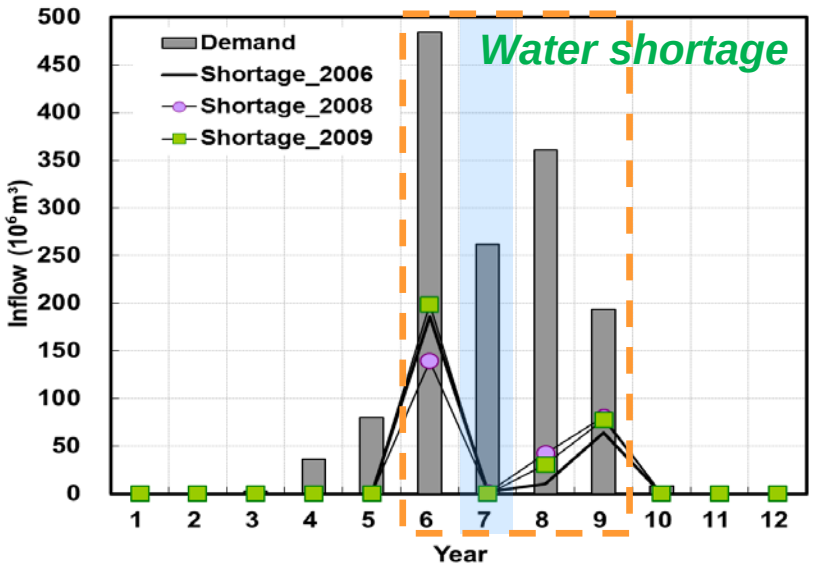
Assessment of impact on agricultural water supply capacity

Monthly demand, supply, shortage on drought period (2006, 2008, 2009)

- ✓ **Water supply capacity (2004~2011)**
  - Municipal and industrial water 98.5%,
    Agricultural water 86.4%
- ✓ **Water supply capacity (drought period)**
  - 2006 : Agricultural water 81.6%
  - 2008 : Agricultural water 81.5%
  - 2009 : Agricultural water 78.5%







Summary & Concluding remarks

- ***The agricultural water demand and supply capacity were evaluated by SWAT streamflow routing and MODSIM water balance networks***
  - ✓ ***The SWAT was calibrated using the observed dam inflow data***
  - ✓ ***The simulated streamflow using SWAT model is used to inflow for each watershed as an input data of MODSIM model.***
  - ✓ ***Using MODSIM model, water balance networks that consider agricultural irrigation facilities were designed for the Geum River basin.***

- ***By MODSIM run for 8 years from 2004 to 2011, the agricultural water shortage had occurred during the drought years of 2006, 2008, and 2009.***

- ***The agricultural water shortage could be calculated as 282 $10^6 m^3$, 286 $10^6 m^3$, and 329 $10^6 m^3$ respectively.***

- ***The results of this research should be identified and incorporated into water resources planning and management in order to promote more sustainable water demand and water availability for a stream watershed of our country.***

Thank you

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