SWAT Soil & Water Assessment Tool

Assessment of Future Climate Change Impact on Groundwater Behavior of Geum River Basin in South Korea Using SWAT

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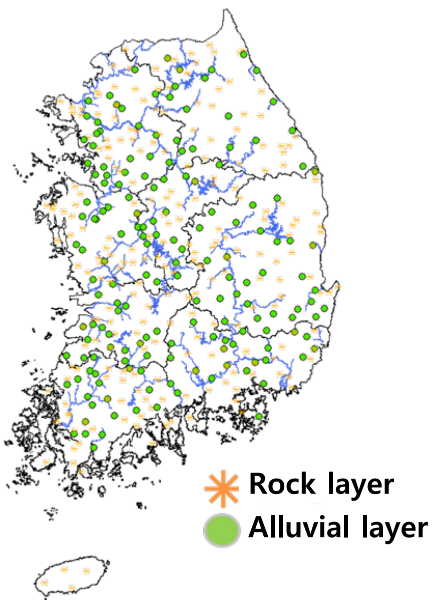
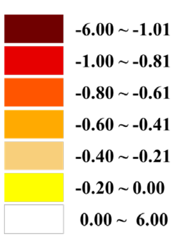
Contents

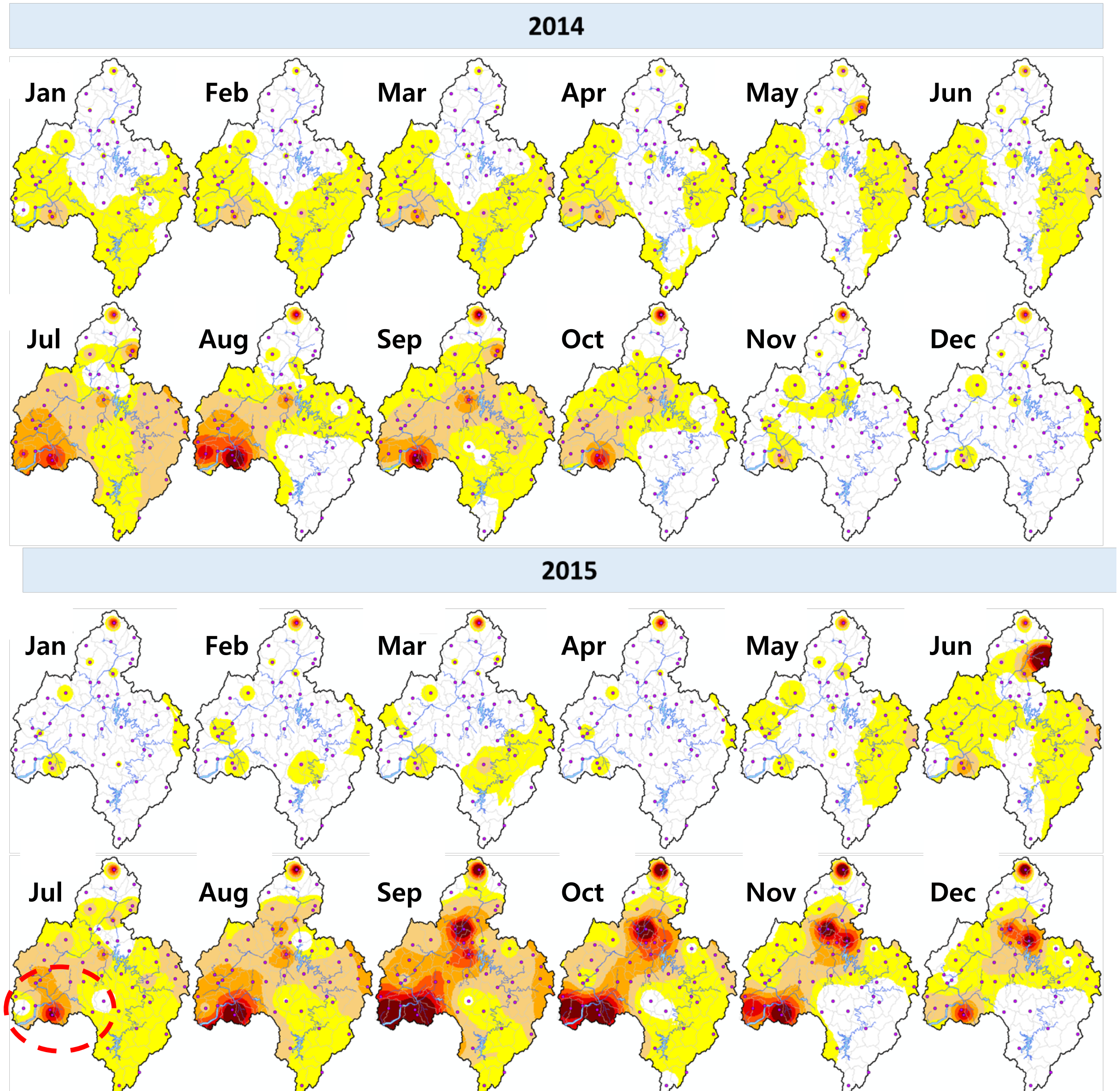
Groundwater shortage *(Geum River basin)*

- **Comparison with Normal year**
  (2000-2015)
  Groundwater level fluctuation distribution

Point Data
166 Station data from KMA



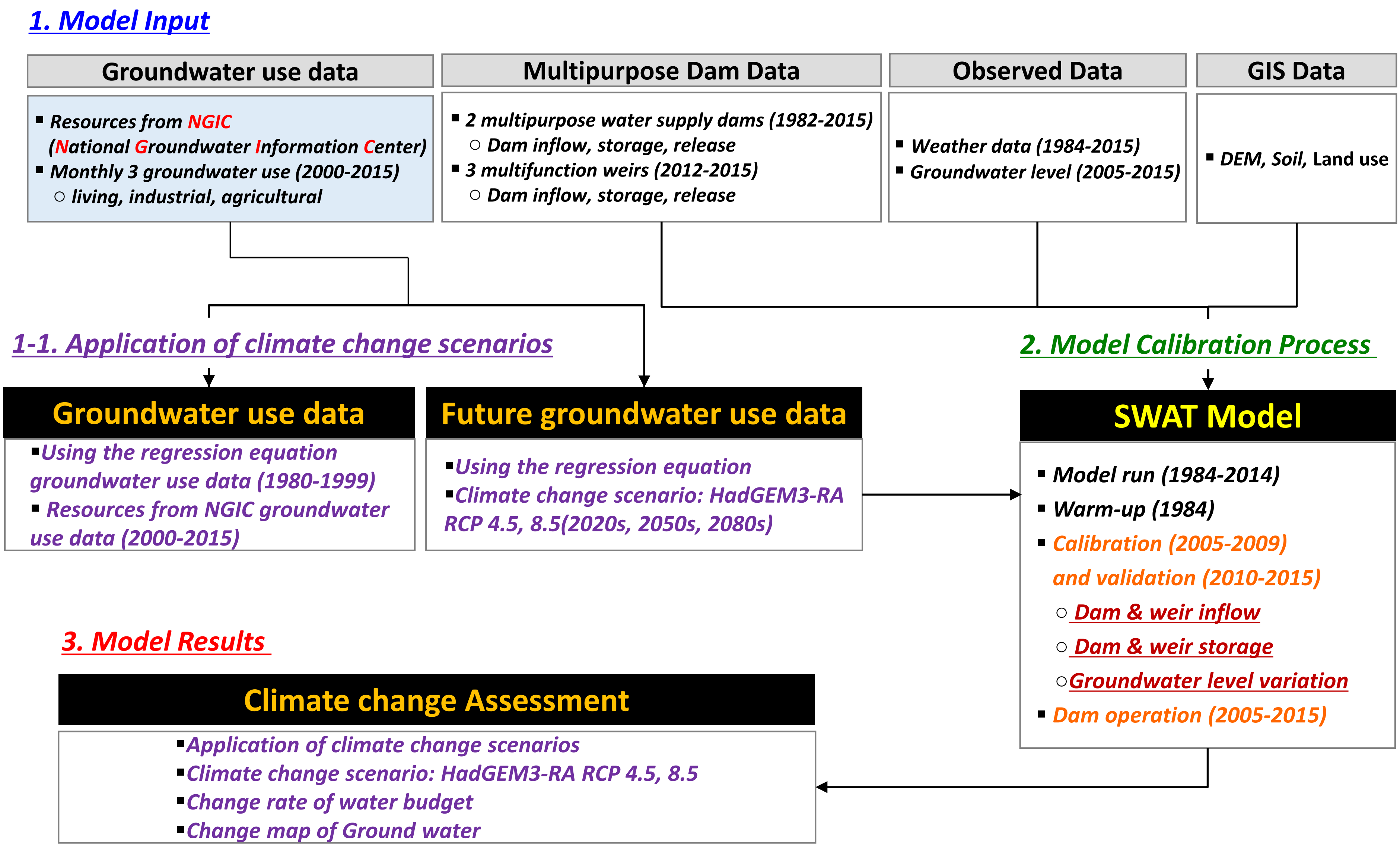




Introduction

- According to the IPCC Fourth Report (2007), the most vulnerable part of future climate change was selected as the change in **water availability** due to the time-space change of the precipitation pattern.
- The IPCC Fifth Report (2014) proposes water diversification and integrated water management, especially in Asia, such as **water recycling**.
- **If the flow rate is slow and continuous, such as groundwater changes, the effects of surface climate change can not be readily perceived. But, If fluctuations due to surface changes begin to be observed in the groundwater environment, the effects are much longer than the surface. Therefore, an analysis of groundwater behavior is required for efficient management of water resources following future climate changes.**
- **The purpose of this study is to evaluate the groundwater level behavior of Geum river basin (9,645.5 km^2) under future climate change scenario projection periods using SWAT.**

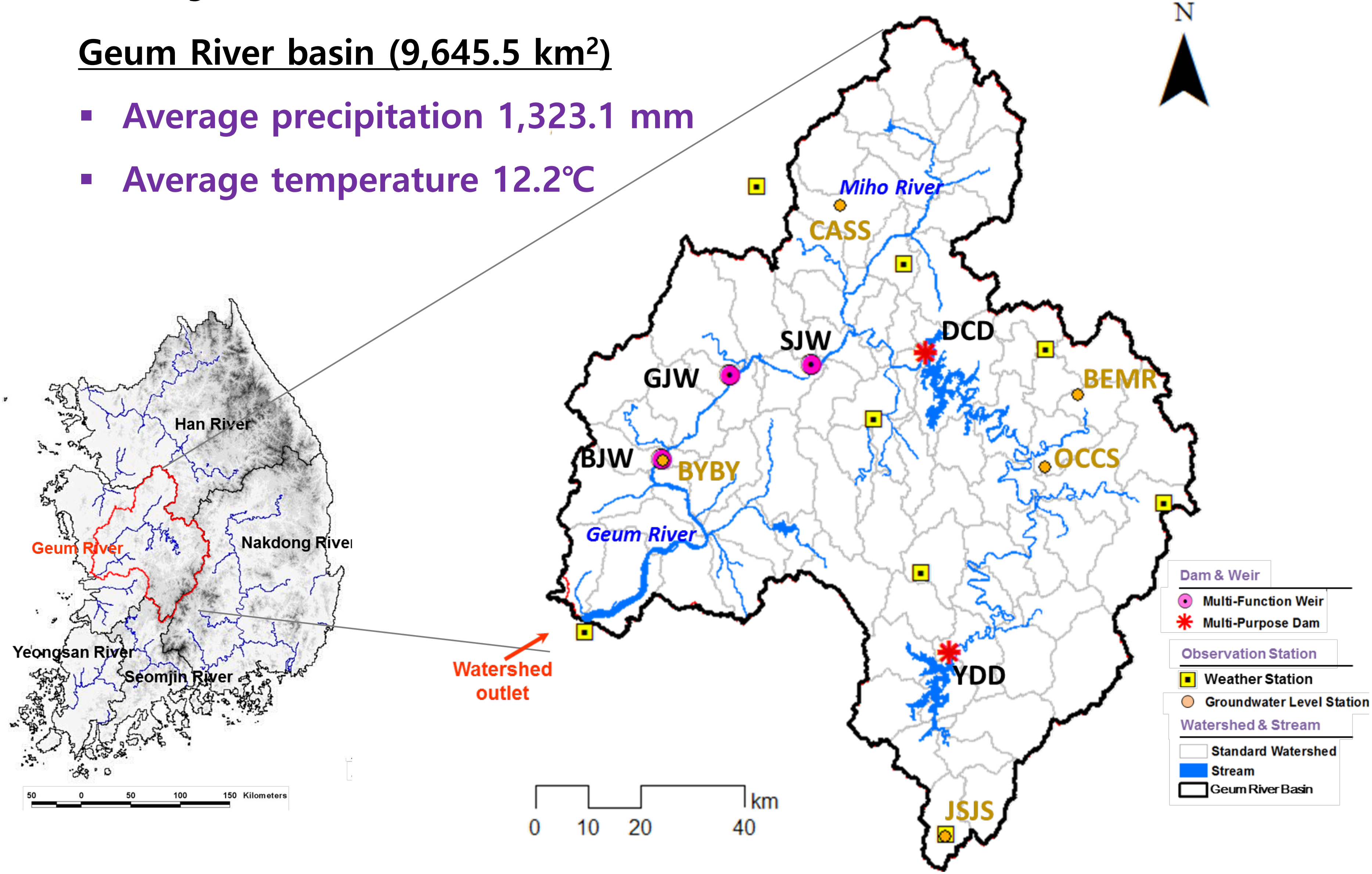
Flowchart of this study



Study Area

Geum River basin (9,645.5 km²)

- Average precipitation 1,323.1 mm
- Average temperature 12.2℃

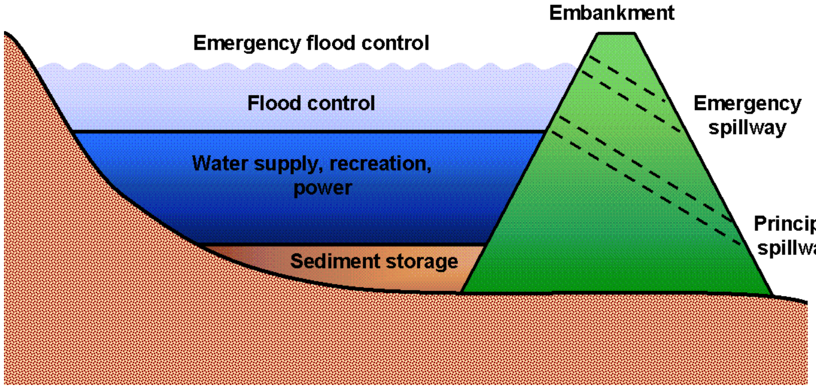


SWAT model

- **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)



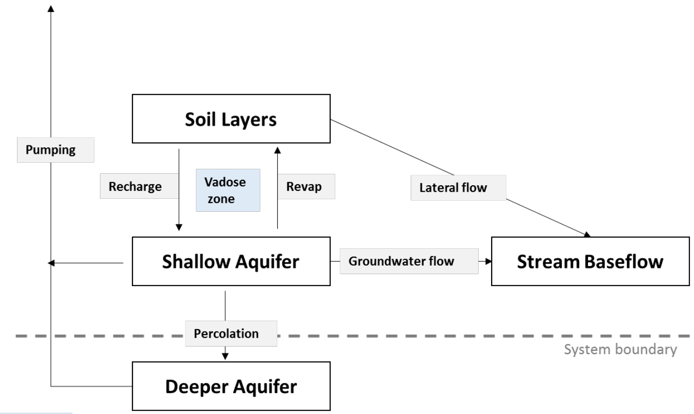
- **Reservoir**

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

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).

SWAT model

- **Groundwater**



Shallow aquifer

$$aq_{sh,i} = aq_{sh,i-1} + w_{rchrg,sh} - Q_{gw} - W_{revap} - W_{pump,sh}$$

$aq_{sh,i}$ = Amount of water stored in the shallow aquifer on day i (mm H_2O)
$aq_{sh,i-1}$ = Amount of water stored in the shallow aquifer on day i-1 (mm H_2O)
$W_{rchrg,sh}$ = Amount of recharge entering the shallow aquifer on day i (mm H_2O)
Q_{gw} = Groundwater flow or base flow into the main channel on day i (mm H_2O)
W_{revap} = Amount of water moving into the soil zone in response to water deficiencies on day i (mm H_2O)
W_{pump} = Amount of water removed from the shallow aquifer by pumping on day i (mm H_2O)

Groundwater flow / base flow

$$Q_{gw} = \frac{8000 \cdot K_{sat}}{L_{gw}^{\;2}} \boxed{h_{wtbl}}$$

- **Extract HRU value at the point where the ground water monitoring system is installed.**
- **SWAT does not output the groundwater level as a result.**
- **SA_ST – GWQMN = Groundwater variation**
- **Actual average +(SA_ST-GWQMN) = Groundwater level**

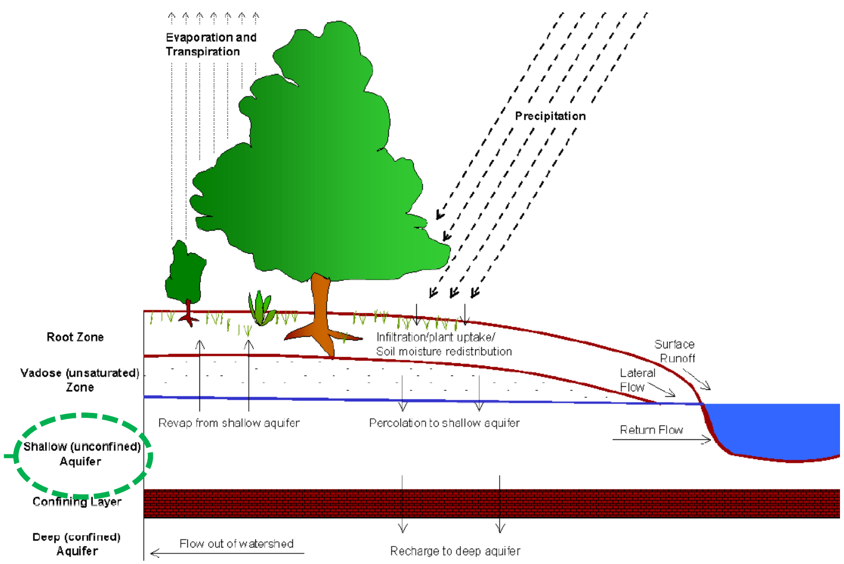
SA_ST: shallow aquifer storage (mm)

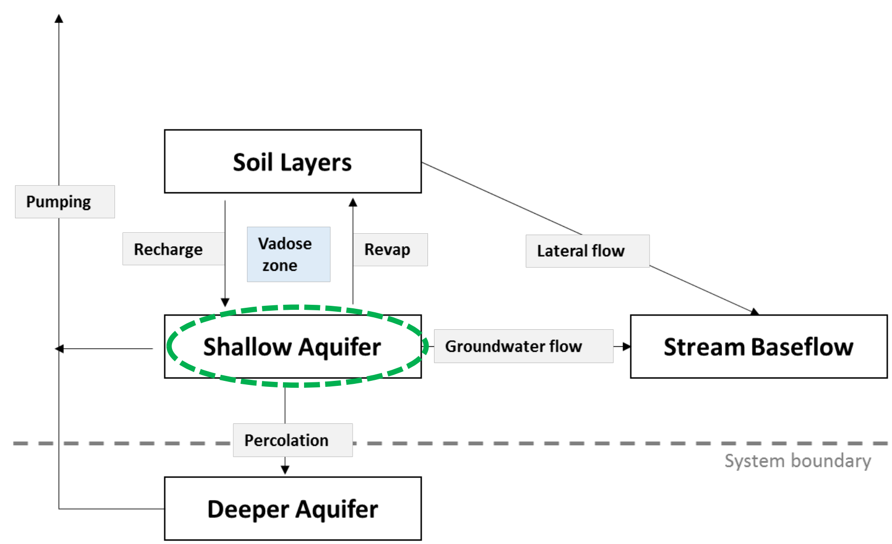
GWQMN: threshold water level in shallow aquifer for base flow (mm)

Q_{gw} = Groundwater flow or base flow into the main channel on day i (mm H_2O)
K_{sat} = hydraulic conductivity of the aquifer (mm/day)
L_{gw} = Distance from the ridge or subbasin divide for the groundwater system to the main channel (m)
h_{wtbl} =water table height (m)

SWAT Input Data

- **WUS (Water USe input file, $10^4 m^3$)**
  - Consumptive water is a management tool that removes water from the basin.
  - This file is used to simulate removal of water for irrigation outside the watershed or removal of water for urban/industrial use.

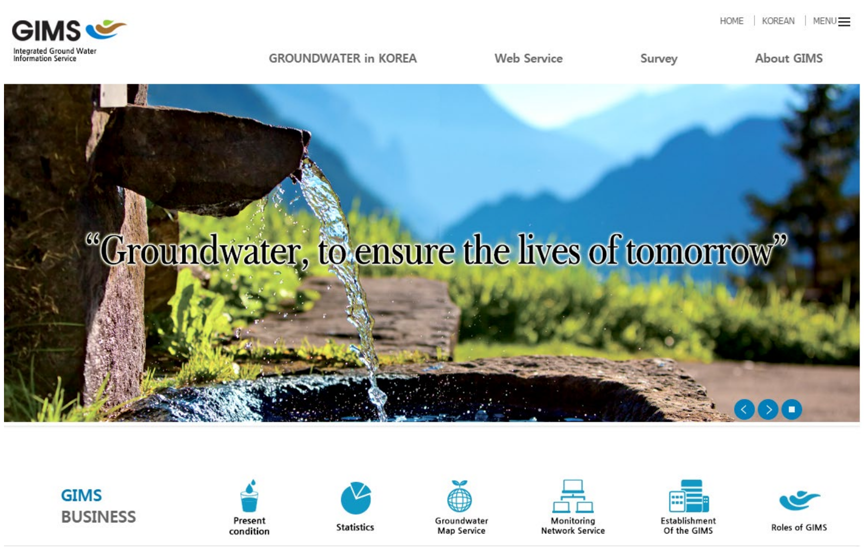




- WUPND : Average daily water removal from the **pond** for the month
- WURCH : Average daily water removal from **reach** for the month
- **WUSHAL : Average daily water removal from the shallow aquifer for the month**
- WUDEEP : Average daily water removal from the **deep aquifer** for the month

SWAT Input Data

- **Future Groundwater use data**
  - **Groundwater use data** are available on the website of **National Groundwater Information Center(NGIC).**
  - The NGIC provides **monthly and yearly groundwater use data** at watersheds and administrative districts.
  - In this study, monthly groundwater from 2000 to 2015 use was divided into living, industrial, and agricultural use.
  - Estimated **future groundwater use data** using actual groundwater use data and **regression equation**.



〈표〉 국가지하수 정보센터 보유자료 현황

조사자료	전국 약 48,000 공에 대한 시추, 착정, 양수시험, 전기탐사, 수질자료 등
관측자료	전국 320개 지하수 관측소의 관측자료 일평균
이용실태자료	전국 지자체의 지하수 이용통계 및 시설현황 자료 약 130만

〈표〉 이용실태 제공정보 세부항목

구성	항목	세부항목	비고
지하수 통계	지하수 연보	지하수 조사연보, 지하수 관측연보	홈페이지 정보
	이용통계	지역별 현황, 세부용도별 현황, 유역별 현황, 당해연도 개발	
	허가/신고 현황	-	
	세부용도별 추이	지역별 이용현황추이, 용도별 이용현황추이, 유역별 이용현황 추이	
	이용특성	개발가능량대비, 개발밀도, 공당지하수, 양수능력별, 정호형태별, 토출관직경별, 정호구경별, 정호심도별	
	불용공현황	-	
	수질검사현황	정기수질검사현황, 환경부수질측정망	
	지하수 수위현황	해당연도수위, 연도별 수위	
	지하수관련업체	지하수개발·이용 시공업체, 정화업체, 영향조사기관	

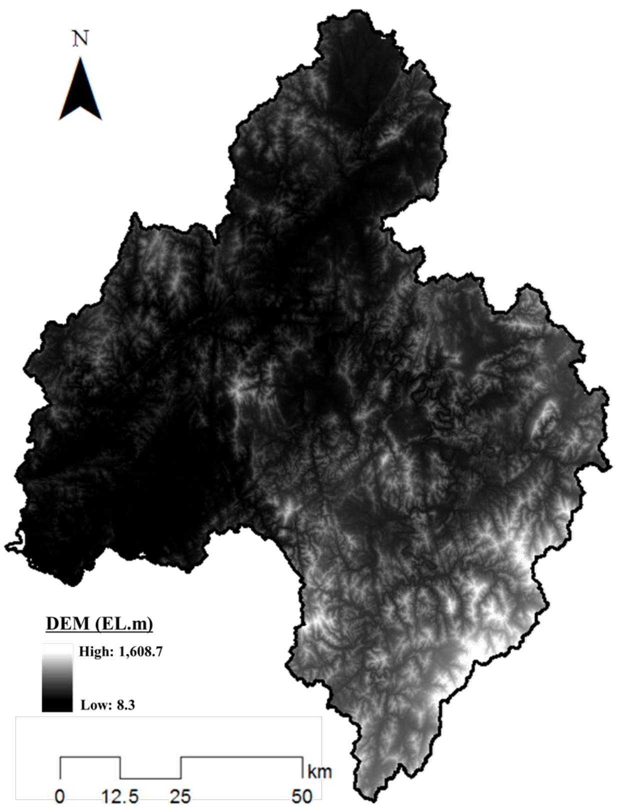
GIMS website (http://www.gims.go.kr)

Data for SWAT model evaluation

GIS Data

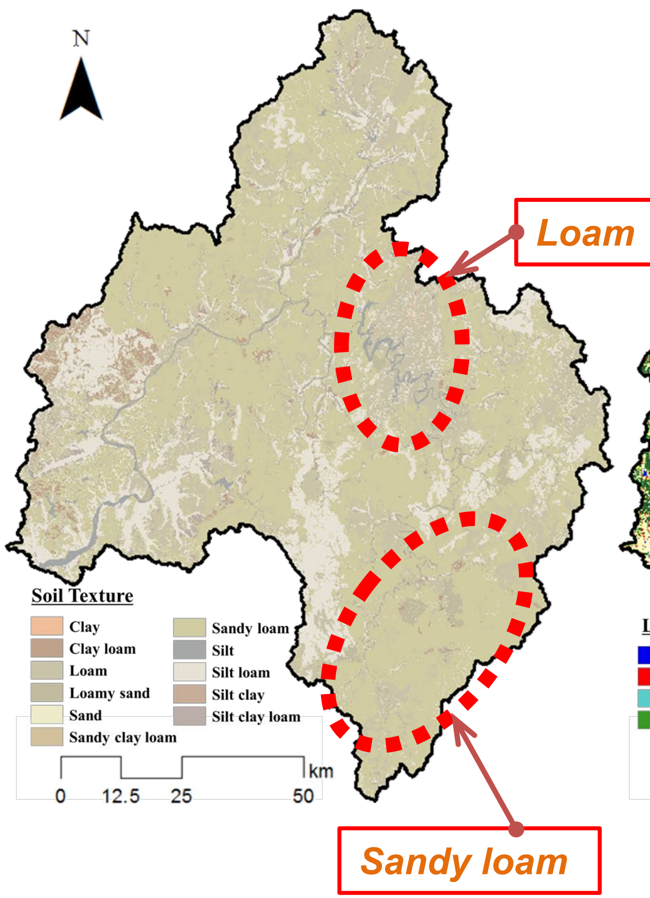
(a) DEM

Elevation : 8 - 1608m (30m grid size)



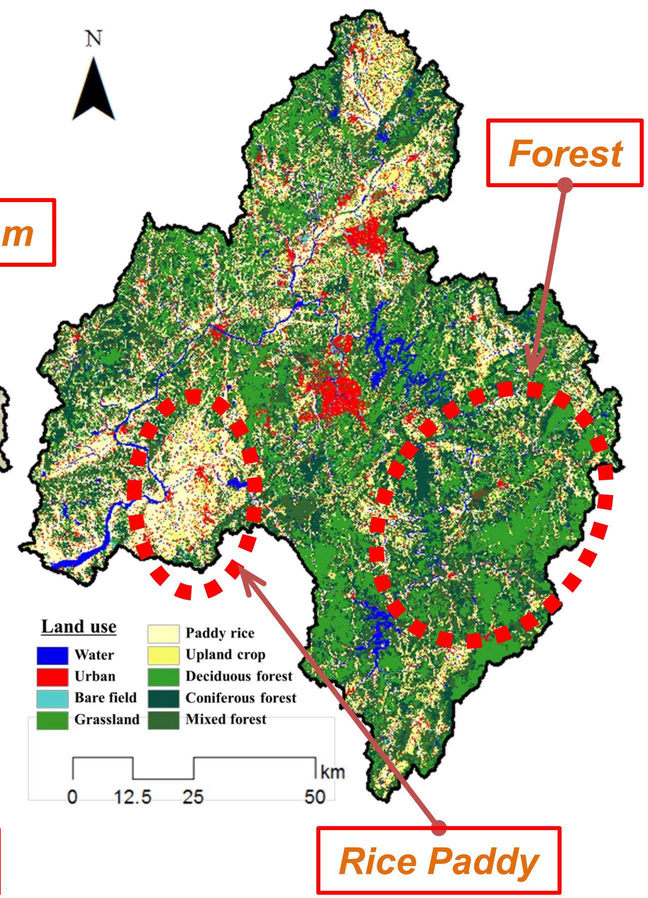
(b) Soil

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



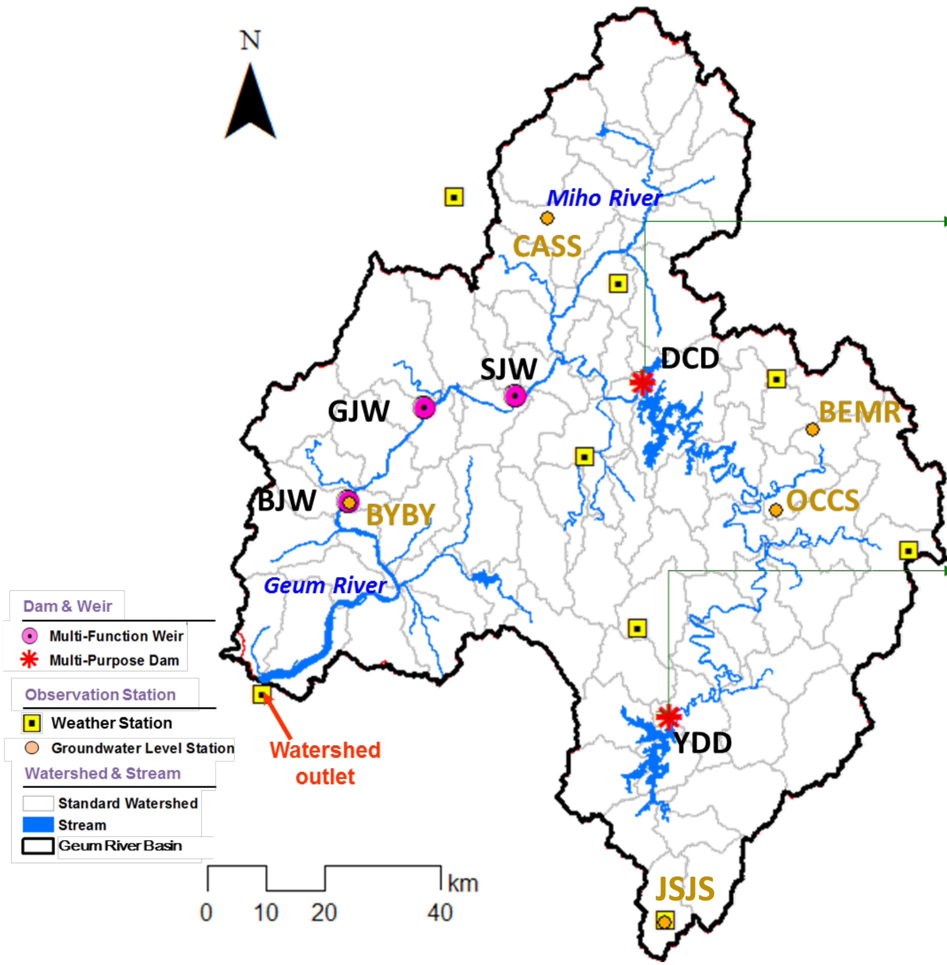
(c) Land cover

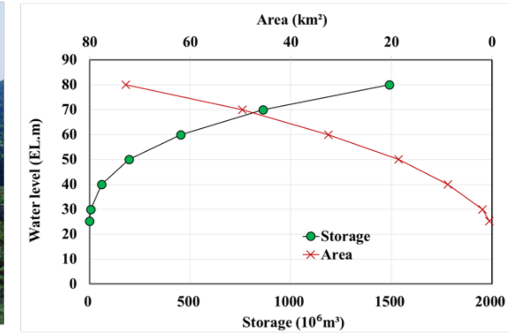
Land cover (2008) : Forest (62%) and Rice paddy (15%)

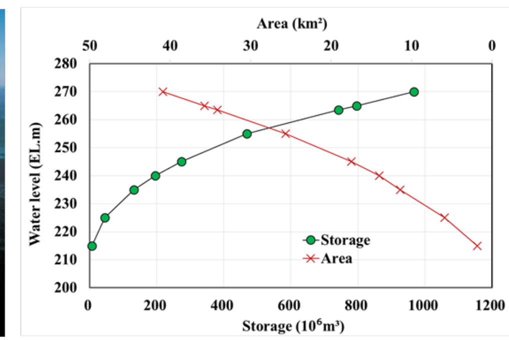


Data for SWAT model evaluation

2 Multi-purpose dam data

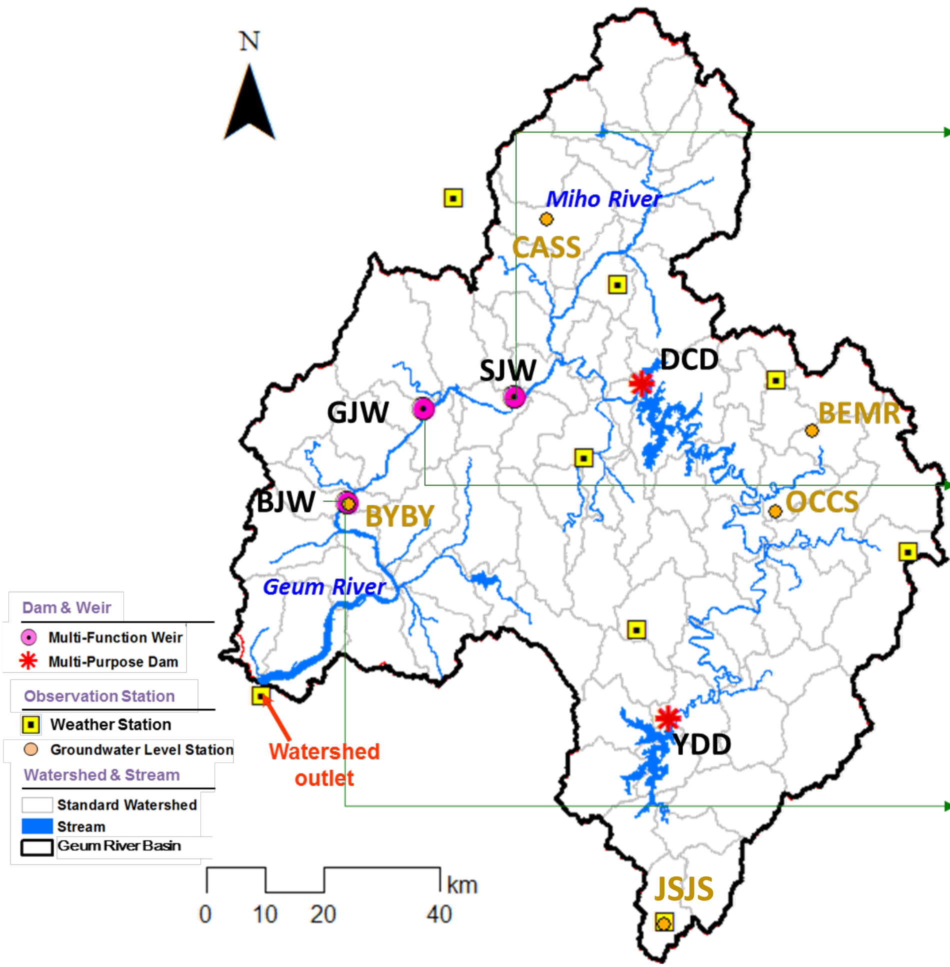


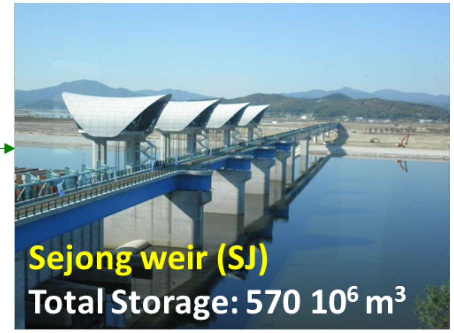


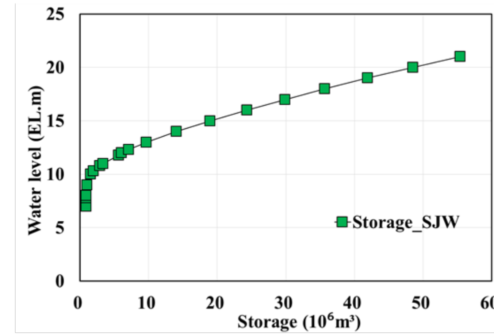


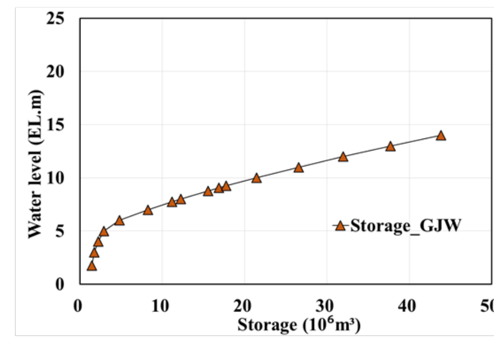
Data for SWAT model evaluation

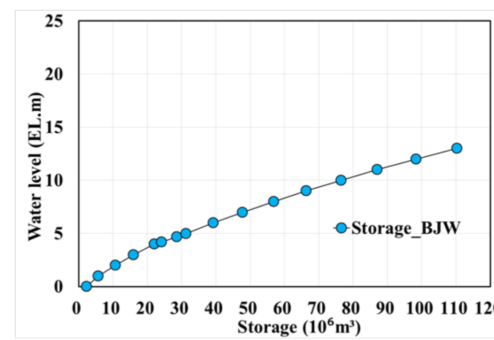
3 Multi-function weir data







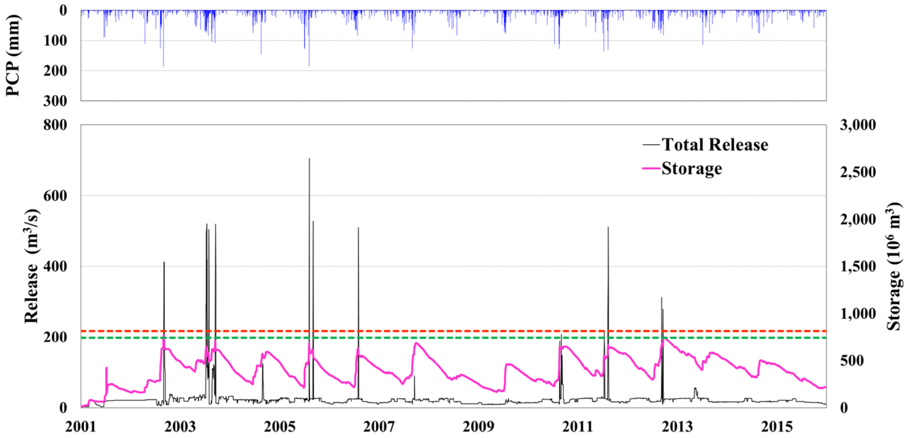




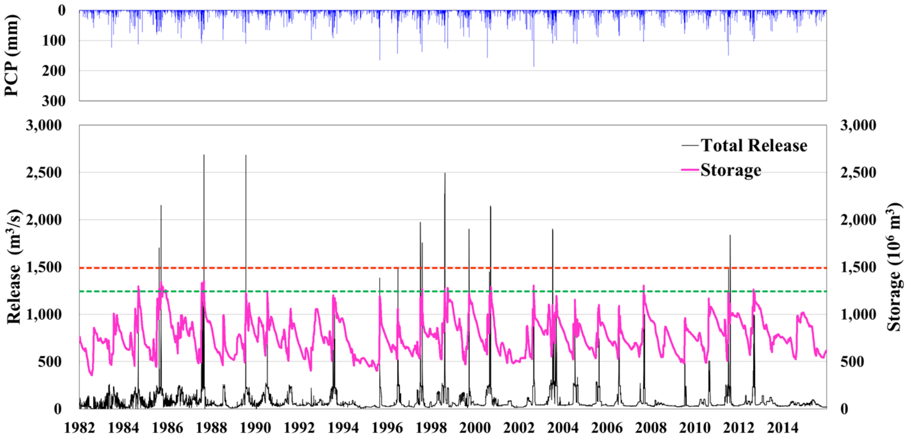
Data for SWAT model evaluation

2 Multi-purpose Dam & 3 Multi-function weir Release and Storage data

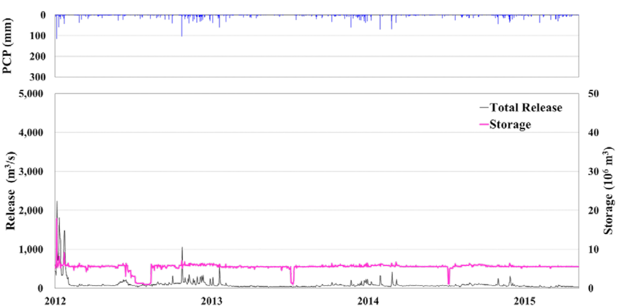
- Yong-Dam Dam (YDD): 2001-2015

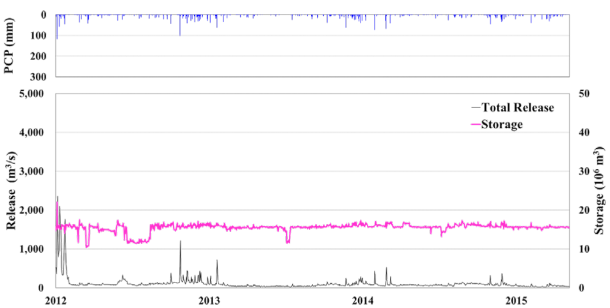


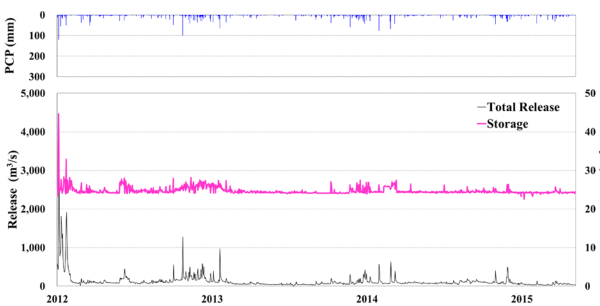
- Dae-Chung Dam (DCD): 1982-2015



- Sejong Weir (SJW): 2012-2015
- Gongju Weir (GJW): 2012-2015
- Bakjae Weir (BJW): 2012-2015



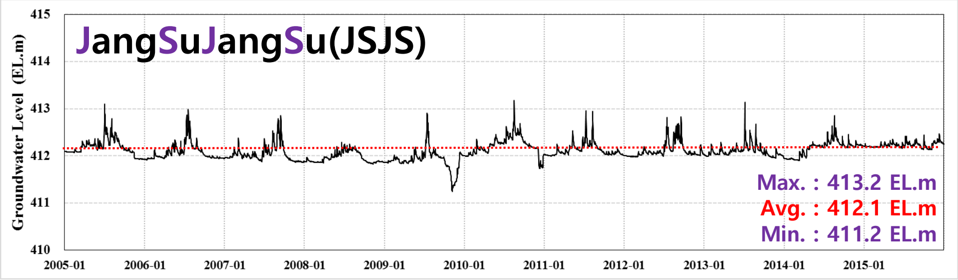


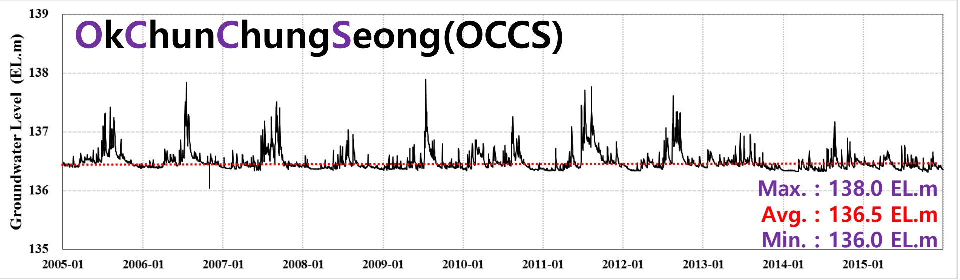


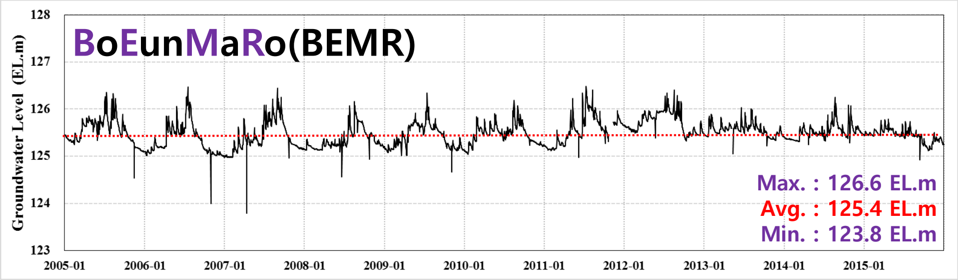
Data for SWAT model evaluation

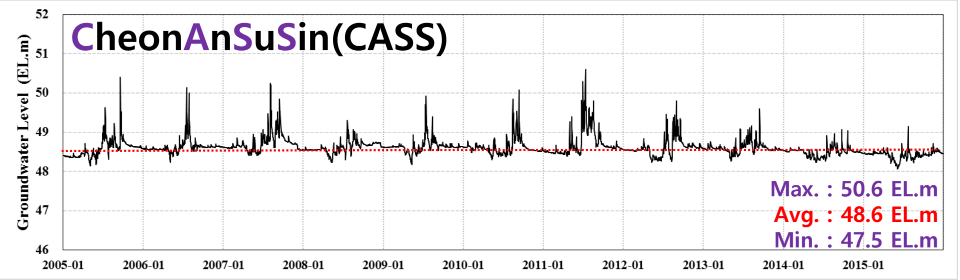
5 Groundwater Level station data

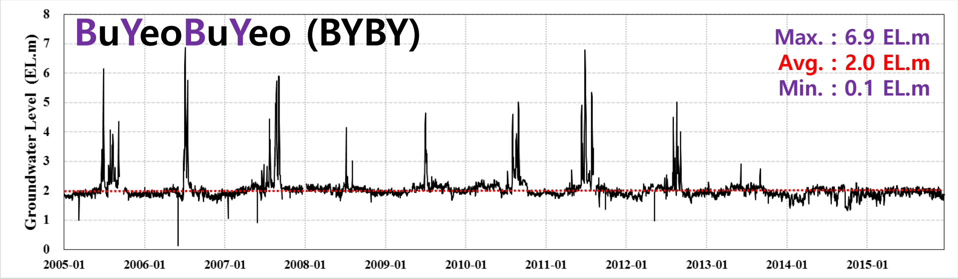
- K-water GIMS(National Groundwater Information Center)
- Alluvium data (2005-2015)











Model Calibration and Validation

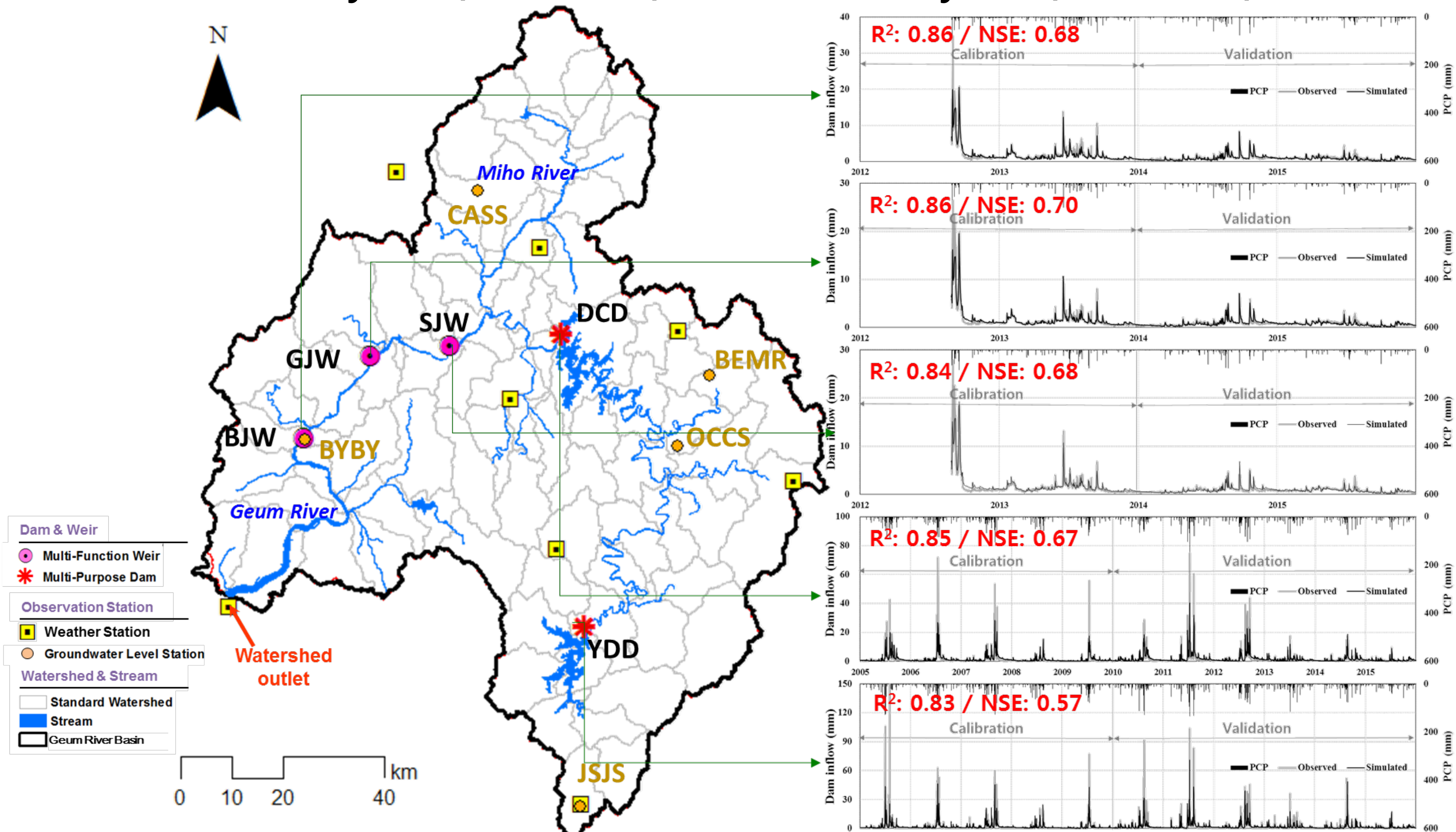
SWAT parameters

Parameters	Definition	Range	Adjusted Value				
			YDD	DCD	SJW	GJW	BJW
Surface runoff							
CH_N(2)	Manning's "n" value for the tributary channel	0.01 to 30	0.16	0.01	0.014	0.014	0.014
Evapotranspiration							
ESCO	Soil evaporation compensation coefficient	0 to 1	0.95	0.95	0.95	0.95	0.95
Groundwater							
GW_DELAY	Delay time for aquifer recharge (days)	0 to 500	150	50	30	31	31
GWQMN	Threshold water level in shallow aquifer for base flow (mm)	0 to 5000	1,000	1,000	1,000	1,000	1,000
ALPHA_BF	Base flow recession constant	0 to 1	0.2	0.2	0.2	0.2	0.2
REVAPMN	Threshold water level in shallow aquifer for revap (mm)	0 to 1000	750	750	750	750	750
GW_REVAP	Groundwater revap coefficient	0.02 to 0.2	0.02	0.02	0.02	0.02	0.02
Reservoir							
RES_ESA	Reservoir surface area when the reservoir is filled to the emergency spillway (ha)	-	3700	7420	350	350	350
RES_EVOL	Volume of water needed to fill the reservoir to the emergency spillway (10^4 m^3)	-	81500	149000	570	1560	2500
RES_PSA	Reservoir surface area when the reservoir is filled to the principal spillway (ha)	-	3390	6750	300	300	300
RES_PVOL	Volume of water needed to fill the reservoir to the principal spillway (10^4 m^3)	-	74250	124160	565	1554	2471
RES_VOL	Initial reservoir volume(104 m3)	-	39821	76857	546	1550	2471
RES_K	Hydraulic conductivity of the reservoir bottom (mm/hr)	0 to 1	0.3	0.1	0.1	0.1	0.1
EVRSV	Lake evaporation coefficient	0 to 1	0.6	0.1	0.6	0.6	0.6

Model Calibration and Validation

2 Multi-purpose Dam & 3 Multi-function weir

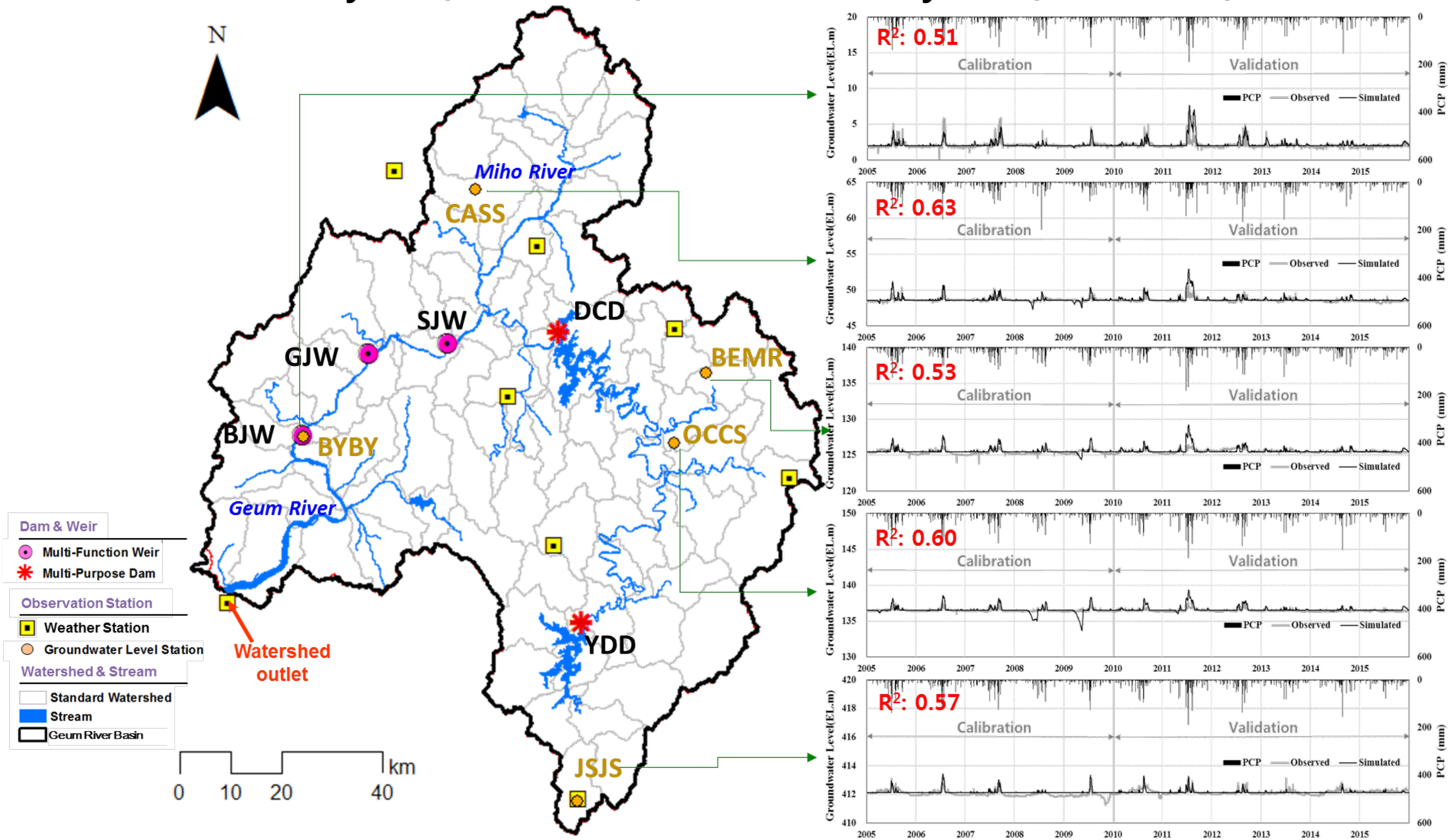
✓ **Calibration**: 5 years (2005-2009) / **Validation**: 6 years (2010-2015)



Model Calibration and Validation

5 Groundwater level

✓ Calibration: 5 years(2005-2009) / Validation: 6 years (2010-2015)



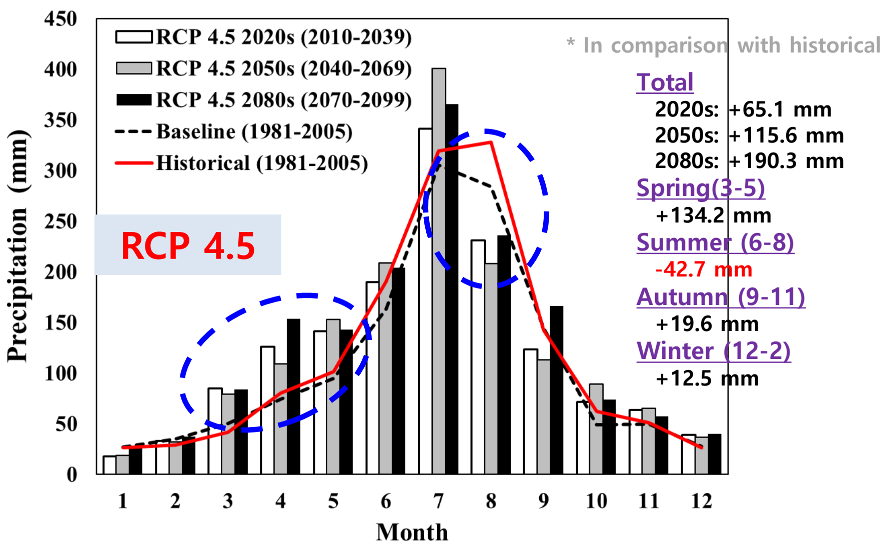
Climate Change Scenario

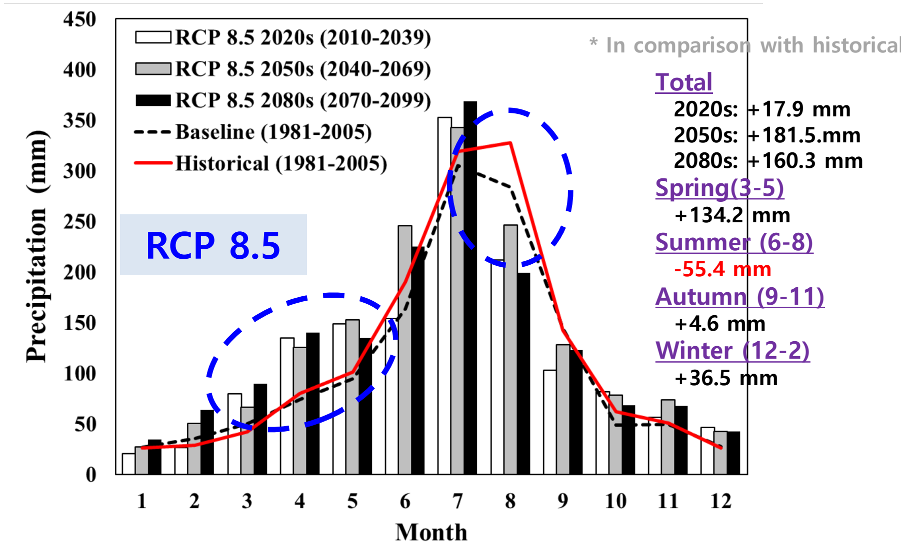
HadGEM3-RA RCP 4.5 and 8.5

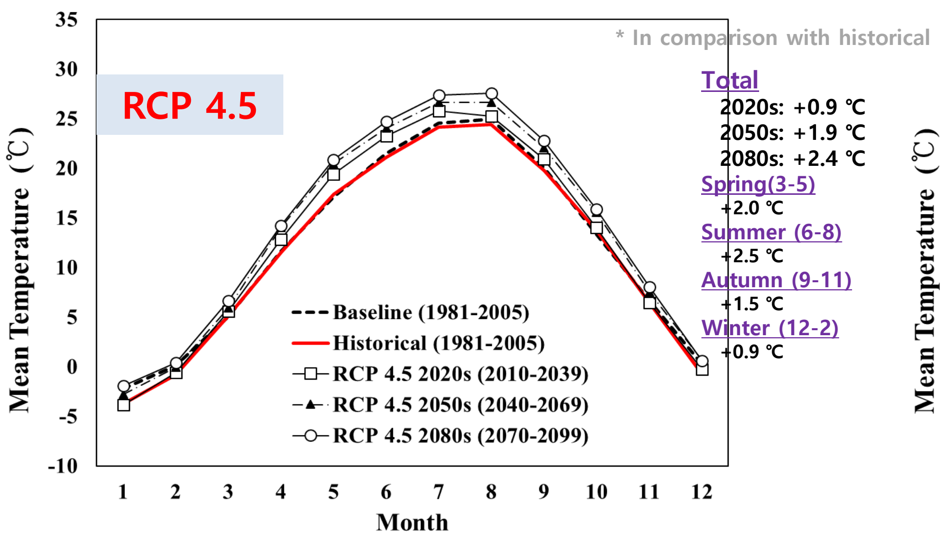
Spring(3-5), Autumn(9-11), Winter(12-2) : Precipitation and Temperature increased.

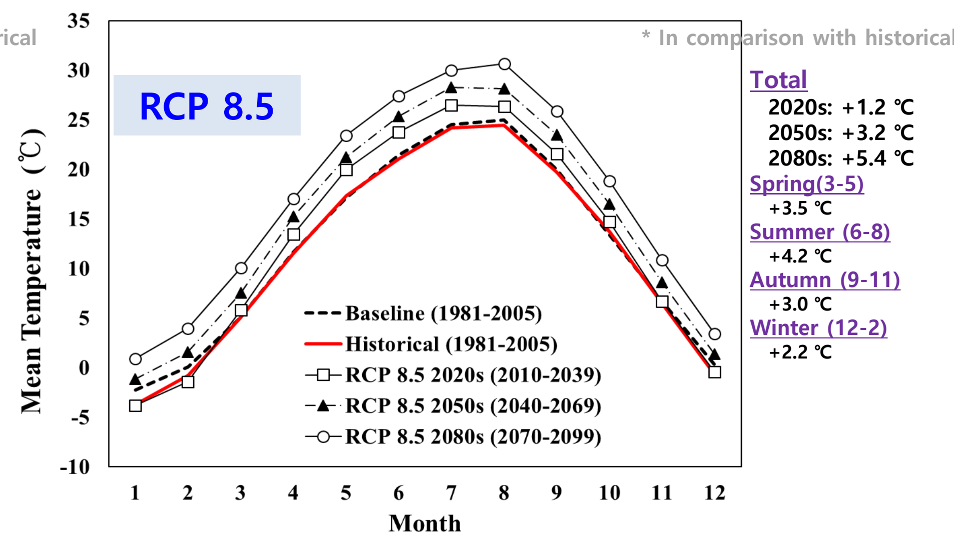
Summer(6-8) : Precipitation decreased and temperature increased.

✓ 2020s: 2010-2039 / 2050s: 2040-2069 / 2080s: 2070-2099

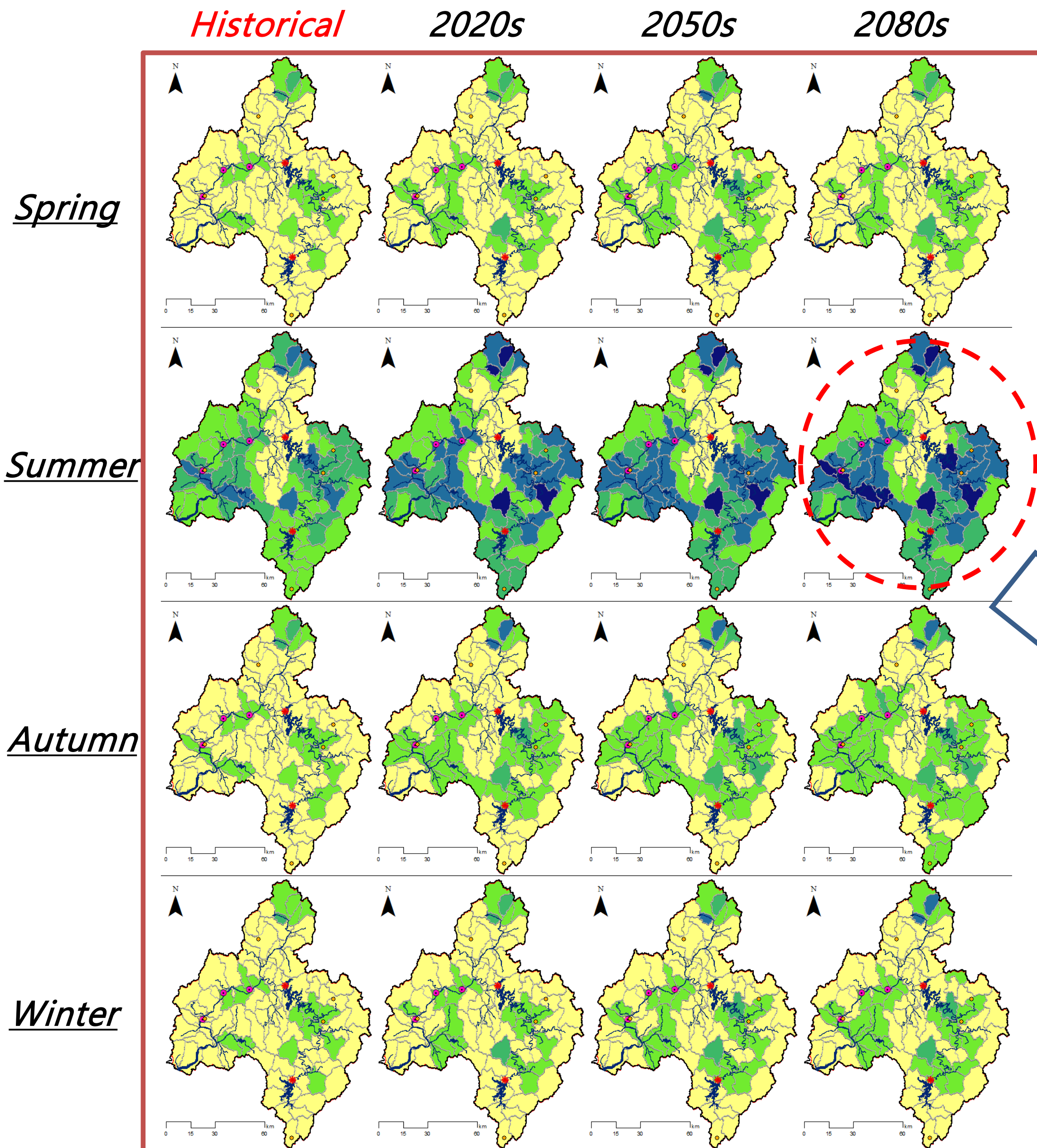








Future groundwater use ($10^4 m^3$) data



➢ **comparison with historical data (2020s, 2050s, 2080s)**

- **Summer(6-8)**

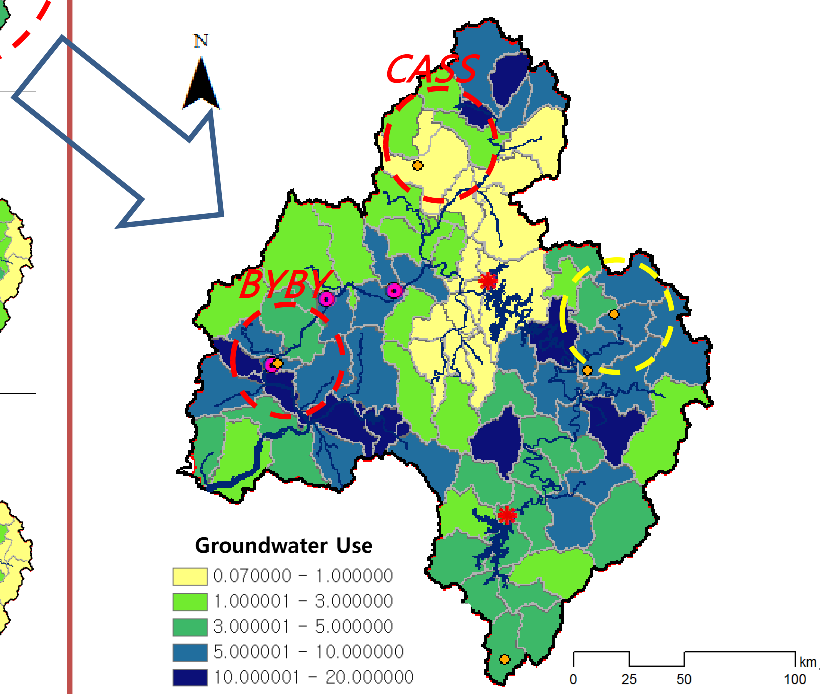
CASS: 2020s(+32%), 2050s(+45%), 2080s(+53%)

BEMR: 2020s(+35%), 2050s(+49%), 2080s(+58%)

OCCS: 2020s(+42%), 2050s(+58%), 2080s(+69%)

BYBY: 2020s(+44%), 2050s(+62%), 2080s(+73%)

JSJS: 2020s(+37%), 2050s(+52%), 2080s(+62%)

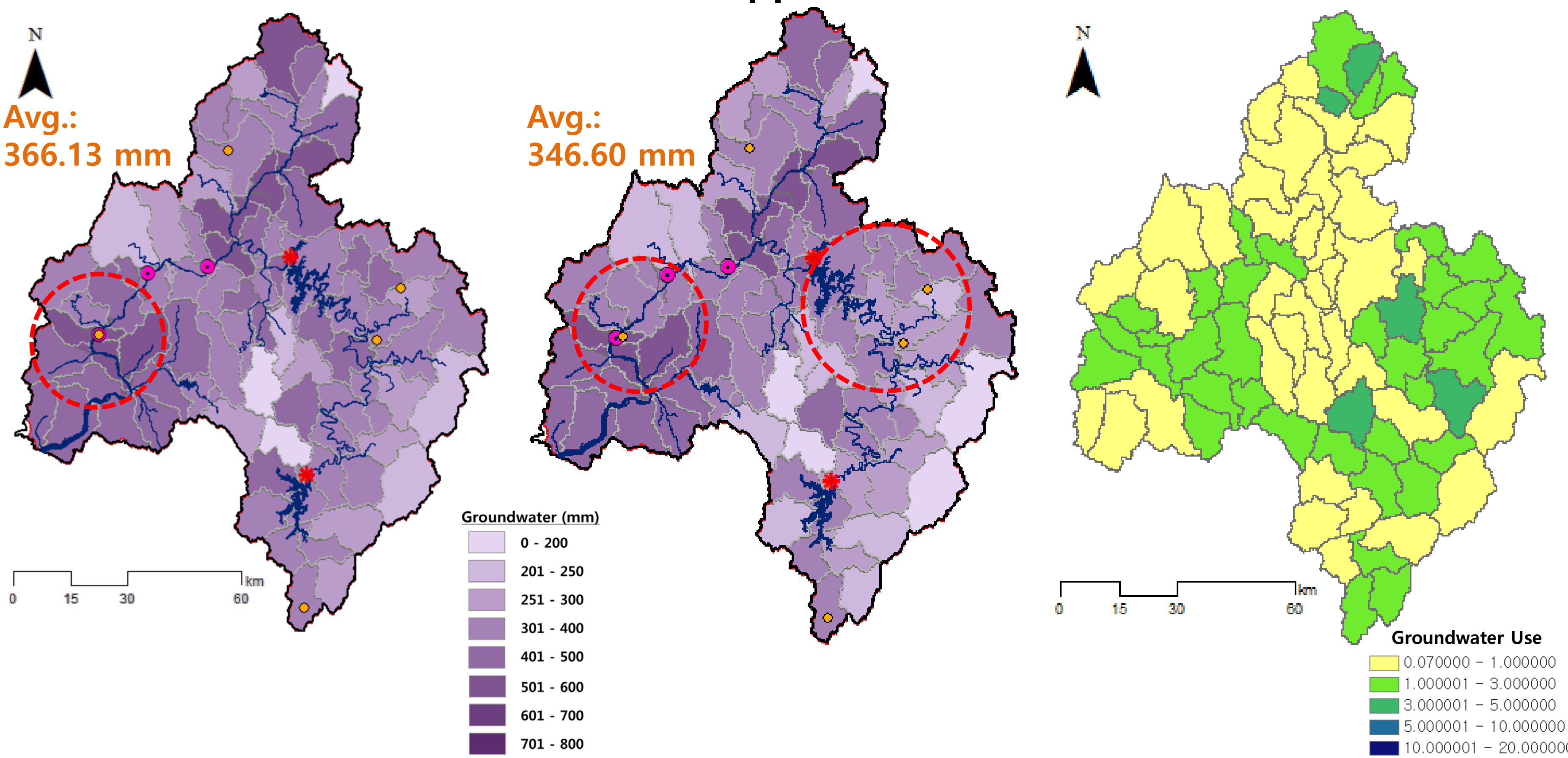


Assessment of GWU Impact on GWF

Historical(1981-2005) Groundwater flow (mm)

- When groundwater use was applied, groundwater **decreased** by **20 mm/yr**.

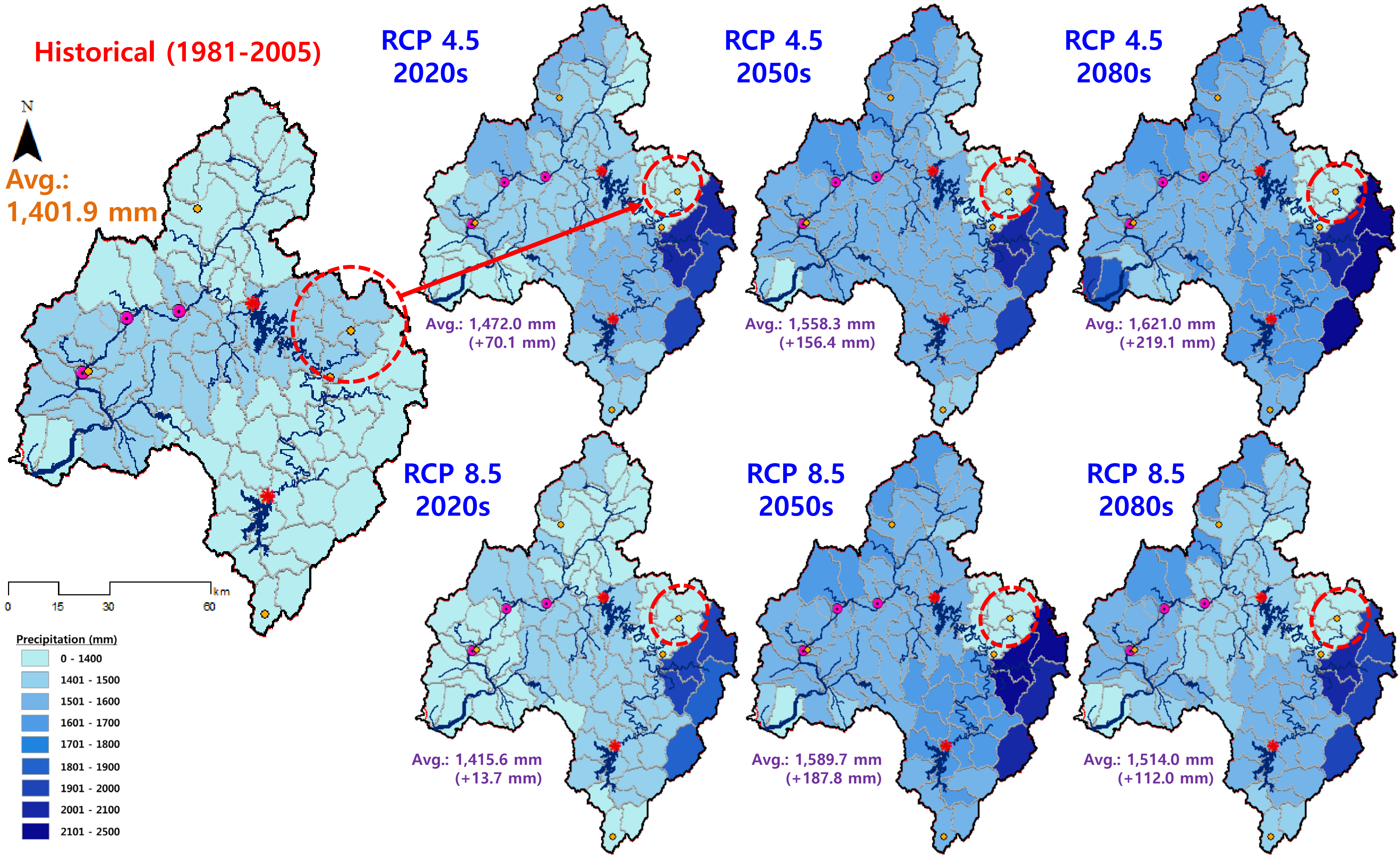
GWF for GWU not applied | **GWF for GWU applied** | **Groundwater use (GWU)**



Assessment of Climate Change

- ✓ 2020s: 2010-2039
- ✓ 2050s: 2040-2069
- ✓ 2080s: 2070-2099

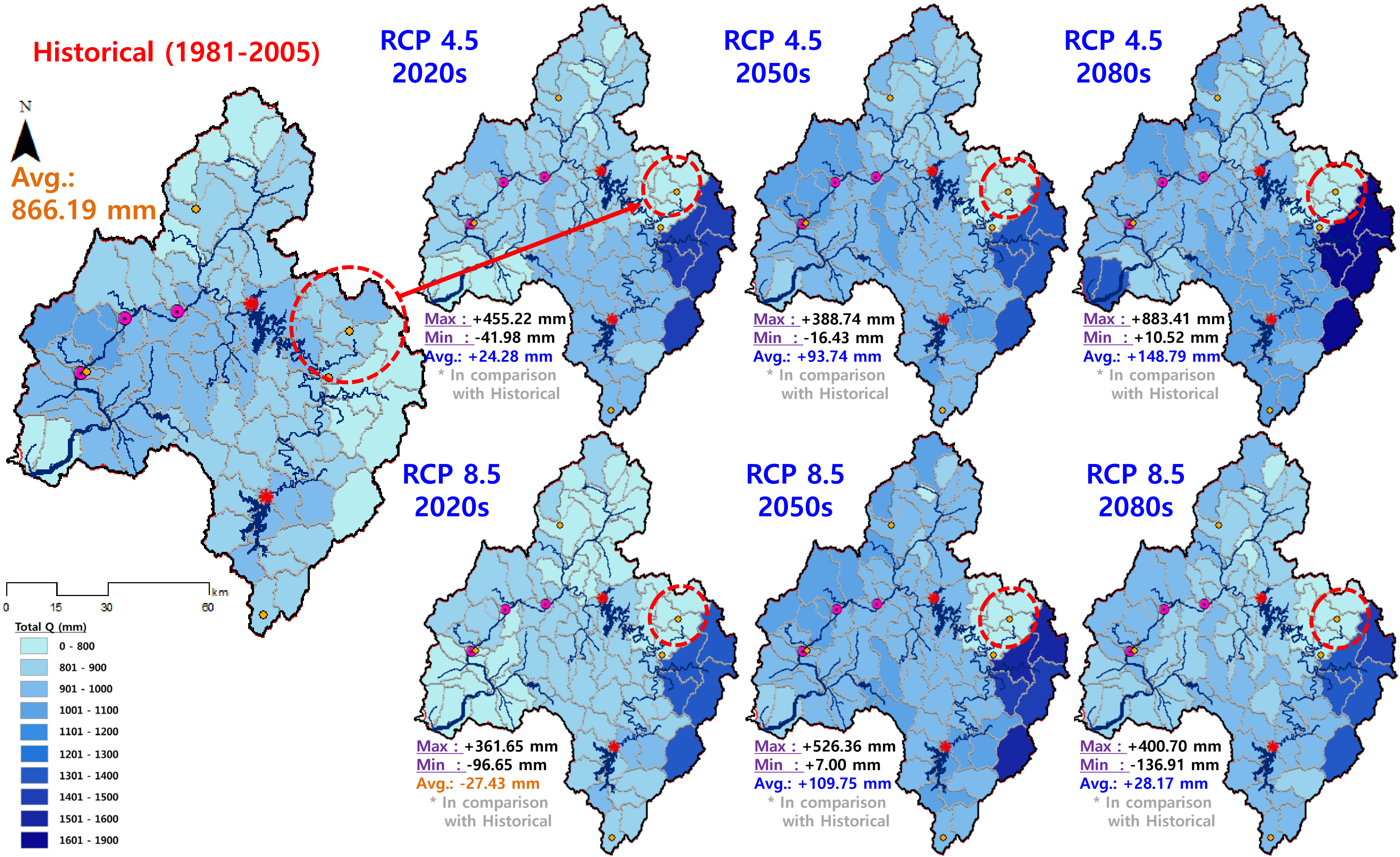
Future Precipitation (mm)



Assessment of Climate Change

- ✓ 2020s: 2010-2039
- ✓ 2050s: 2040-2069
- ✓ 2080s: 2070-2099

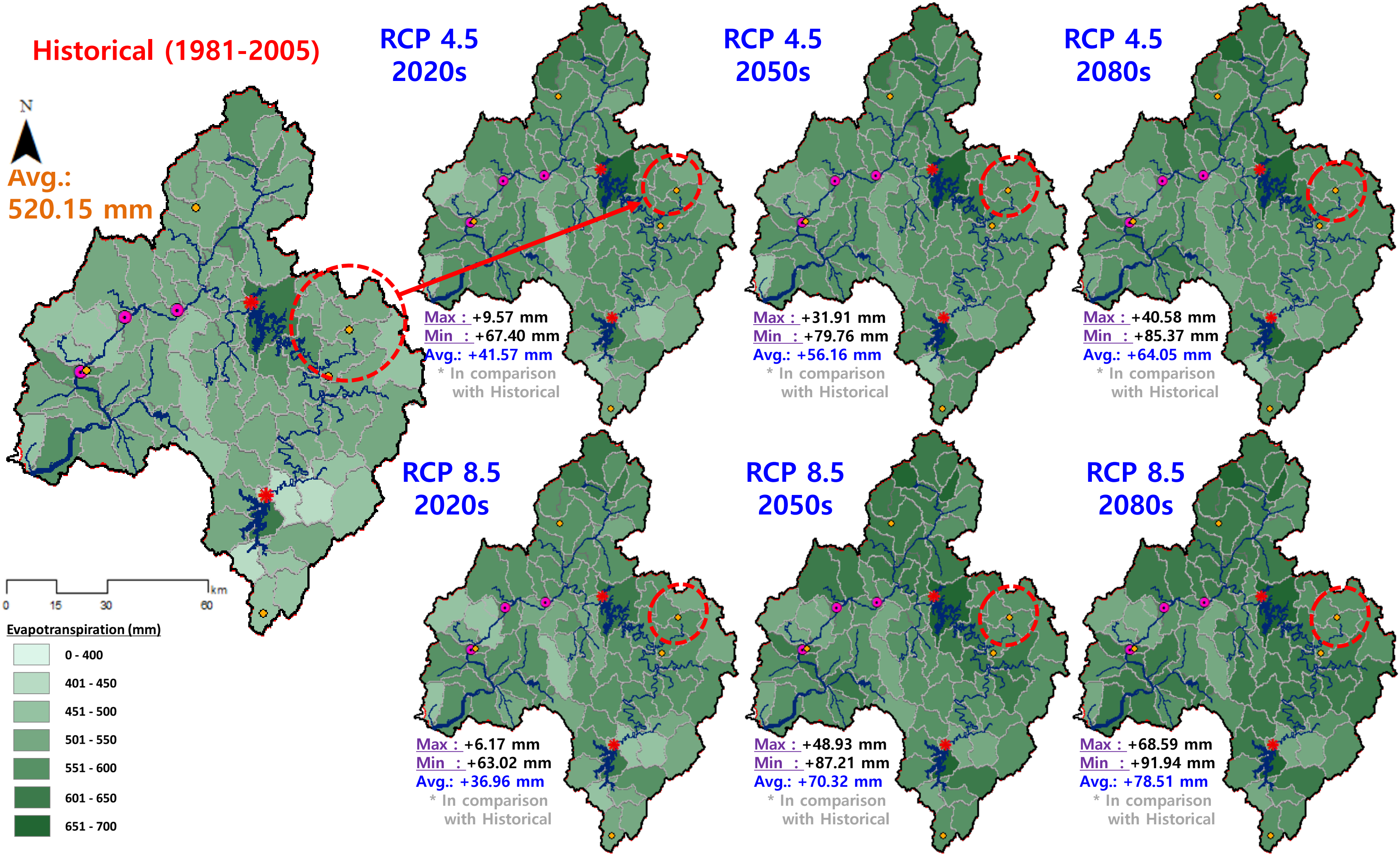
Future Discharge (mm)



Assessment of Climate Change

- ✓ 2020s: 2010-2039
- ✓ 2050s: 2040-2069
- ✓ 2080s: 2070-2099

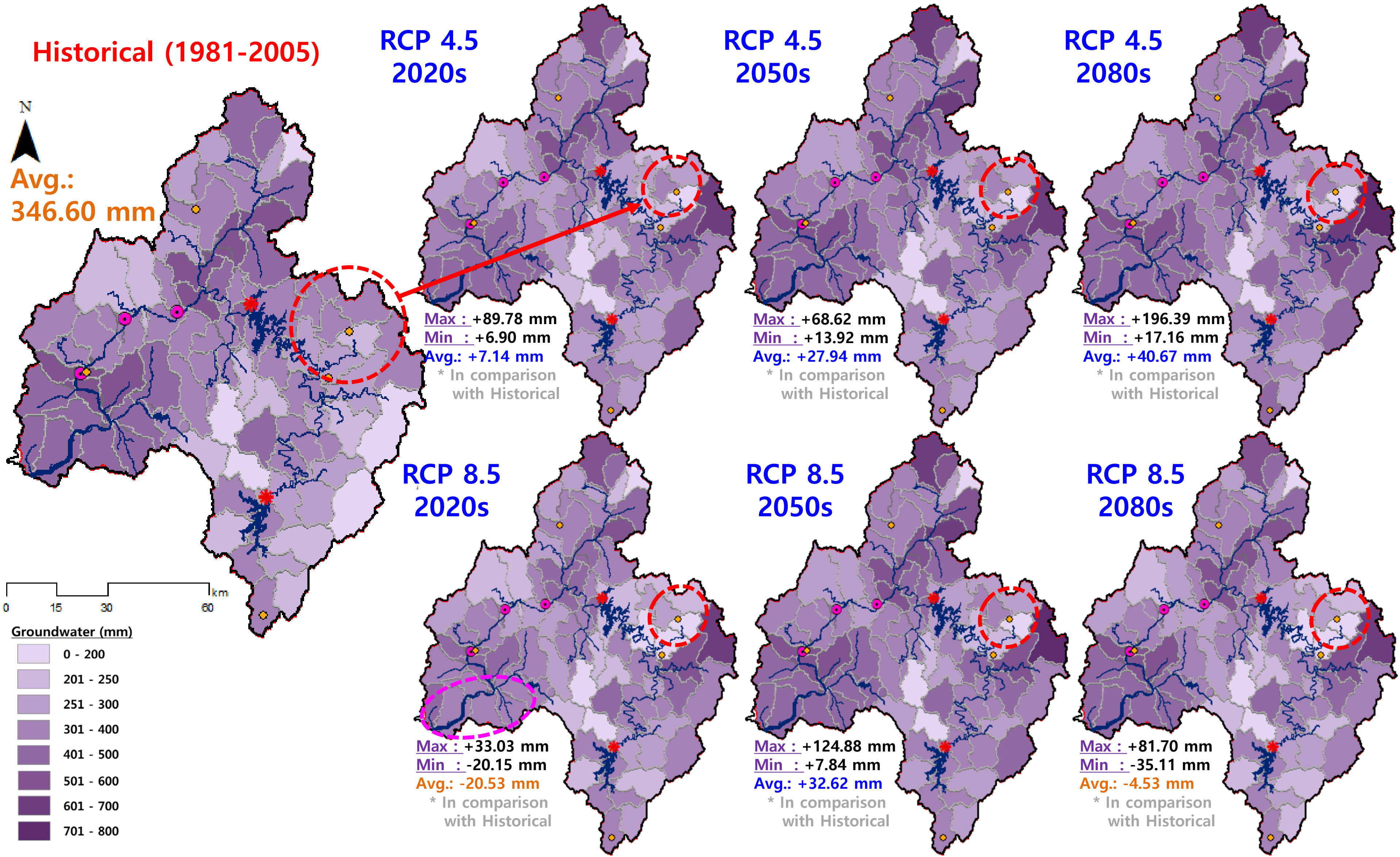
Future Evapotranspiration (mm)



Assessment of Climate Change

- ✓ 2020s: 2010-2039
- ✓ 2050s: 2040-2069
- ✓ 2080s: 2070-2099

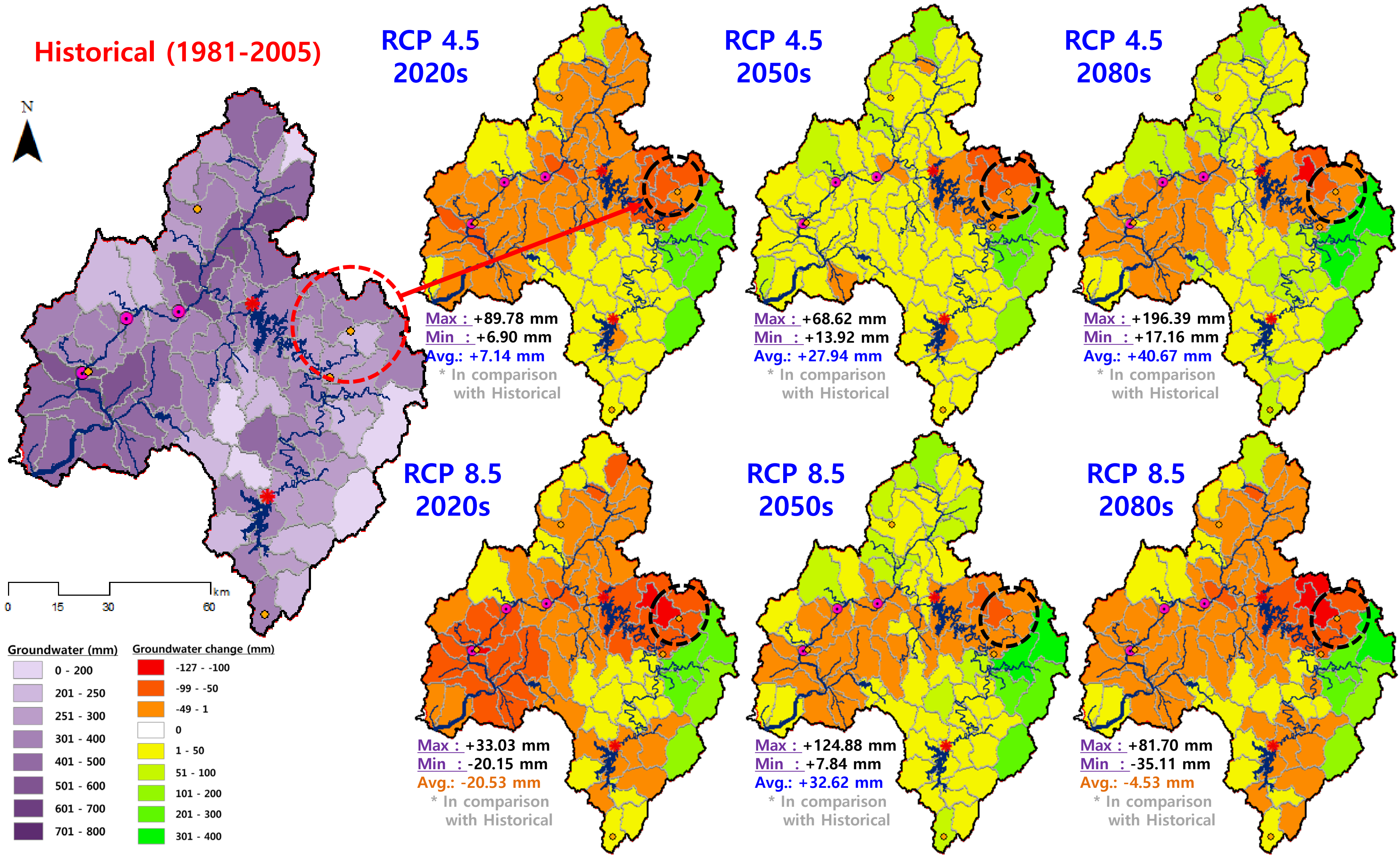
Future Groundwater flow (mm)



Assessment of Climate Change

- ✓ 2020s: 2010-2039
- ✓ 2050s: 2040-2069
- ✓ 2080s: 2070-2099

Future Groundwater flow (mm) changes



Assessment of Climate Change

Future Groundwater Level (EL.m) changes

❖ Average variation of future groundwater level at 5 station

Spring(3-5) Future groundwater level RCP 4.5: ▲, RCP 8.5: ▼

RCP 4.5: **+0.08 m** (2020s: -0.13 m, 2050s: -0.10 m, 2080s: +0.46 m)

RCP 8.5: **-0.05 m** (2020s: -0.15 m, 2050s: +0.15 m, 2080s: -0.16 m)

Summer(6-8) Future groundwater level RCP 4.5 and RCP 8.5: ▼

RCP 4.5: **-0.03 m** (2020s: -0.79 m, 2050s: +1.13 m, 2080s: -0.43 m)

RCP 8.5: **-1.19 m** (2020s: -1.08 m, 2050s: -1.50 m, 2080s: -0.99 m)

Autumn(9-11) Future groundwater level RCP 4.5 and RCP 8.5: ▲

RCP 4.5: **+0.55 m** (2020s: +0.64 m, 2050s: +0.24 m, 2080s: +0.78 m)

RCP 8.5: **+0.04 m** (2020s: +0.21 m, 2050s: +0.08 m, 2080s: -0.16 m)

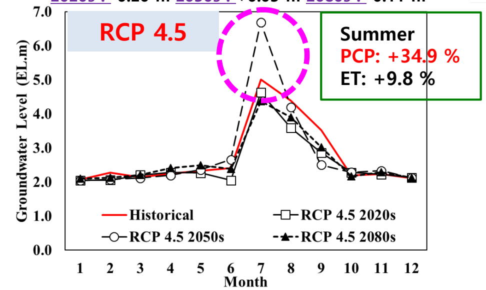
Winter(12-2) Future groundwater level RCP 4.5: ▼, RCP 8.5: ▲

RCP 4.5: **-0.01 m** (2020s: -0.02 m, 2050s: -0.05 m, 2080s: +0.04 m)

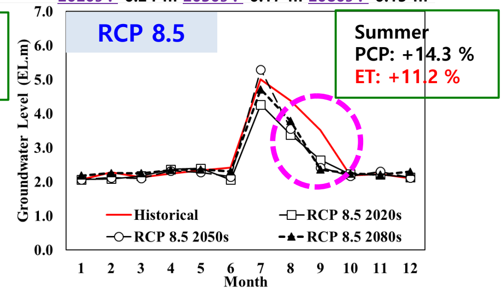
RCP 8.5: **+0.07 m** (2020s: +0.01 m, 2050s: -0.01 m, 2080s: +0.21 m)

BYBY

2020s : -0.20 m 2050s : +0.05 m 2080s : -0.11 m

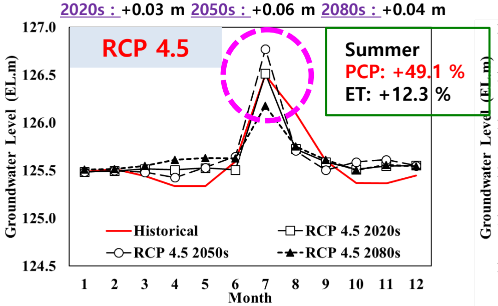


2020s : -0.24 m 2050s : -0.17 m 2080s : -0.13 m

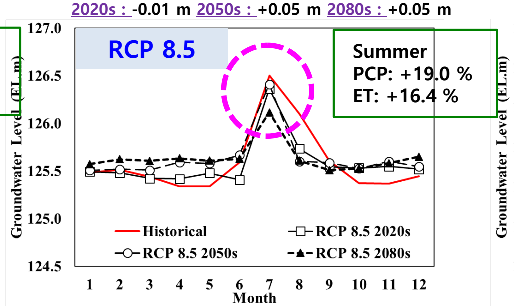


CASS

2020s : +0.03 m 2050s : +0.06 m 2080s : +0.04 m

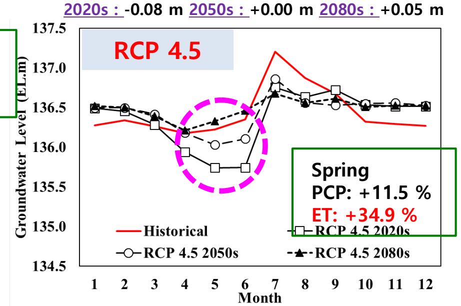


2020s : -0.01 m 2050s : +0.05 m 2080s : +0.05 m

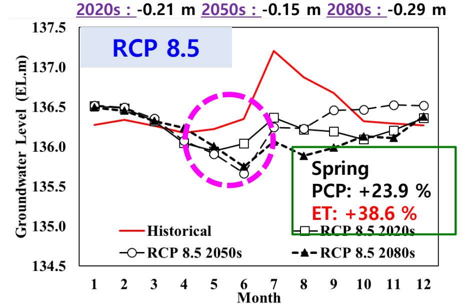


OCCS

2020s : -0.08 m 2050s : +0.00 m 2080s : +0.05 m

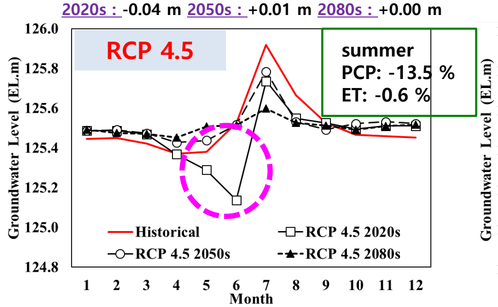


2020s : -0.21 m 2050s : -0.15 m 2080s : -0.29 m

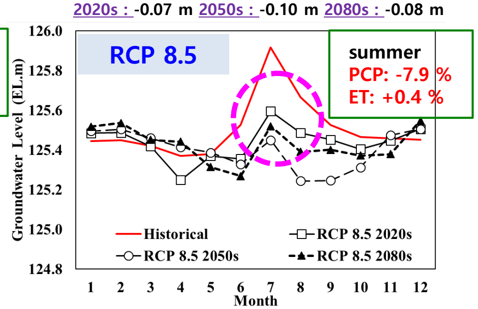


BEMR

2020s : -0.04 m 2050s : +0.01 m 2080s : +0.00 m

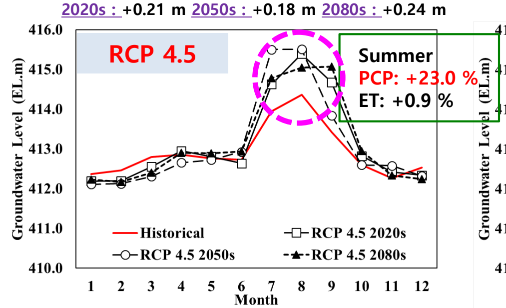


2020s : -0.07 m 2050s : -0.10 m 2080s : -0.08 m

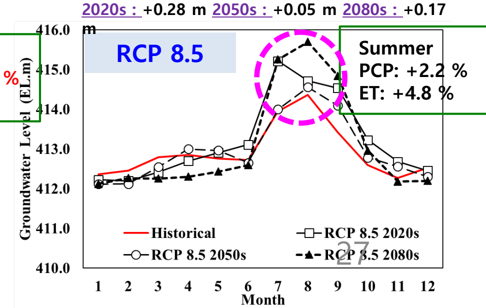


JSJS

2020s : +0.21 m 2050s : +0.18 m 2080s : +0.24 m



2020s : +0.28 m 2050s : +0.05 m 2080s : +0.17 m



Findings and Future researches

- **The purpose of this study is to evaluate future climate change impact on groundwater level behavior considering future groundwater use in Geum River basin (9,645.5 km^2).**

1. HadGEM3-RA RCP 4.5 & 8.5 Climate Change Scenarios

- **Spring(3-5), Autumn(9-11), Winter(12-2): Precipitation and Temperature increased.**
- **Summer(6-8): Precipitation decreased (RCP 4.5 : -42.7 mm, RCP 8.5 : -55.4 mm) and temperature increased (RCP 4.5 : +2.5 ℃, RCP 8.5 : +4.2 ℃).**

2. Future groundwater use (GWU) condition

- **Big increase of GWU in summer period.**
- **Future GWU increased from 32 to 44% in 2020s, from 45 to 62% in 2050s, and from 53 to 73% in 2080s.**

3. Future groundwater level (GWL) changes

- **Spring(3-5): increased by 0.08 m in RCP 4.5, decreased by 0.05 m in RCP 8.5 scenario**
- **Summer(6-8): decreased by 0.03 m and 1.19 m in RCP 4.5 and RCP 8.5 scenarios respectively**
- **Autumn(9-11): increased by 0.55 m and 0.04 m in RCP 4.5 and RCP 8.5 scenarios respectively**
- **Winter(12-2): decreased by 0.01 m in RCP 4.5, increased by 0.07 m in RCP 8.5 scenario**

Thank You

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