2010 SWAT Korea

Assessment of MIROC3.2 hires Climate Change and CLUE-s Land Use Change Impacts on Watershed Hydrology using SWAT

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Soil & Water Assessment Tool SWAT

Contents

Background and Purpose

- The Intergovernmental Panel on Climate Change (IPCC) report reaffirms that "global warming" is occurring (IPCC, 2001).

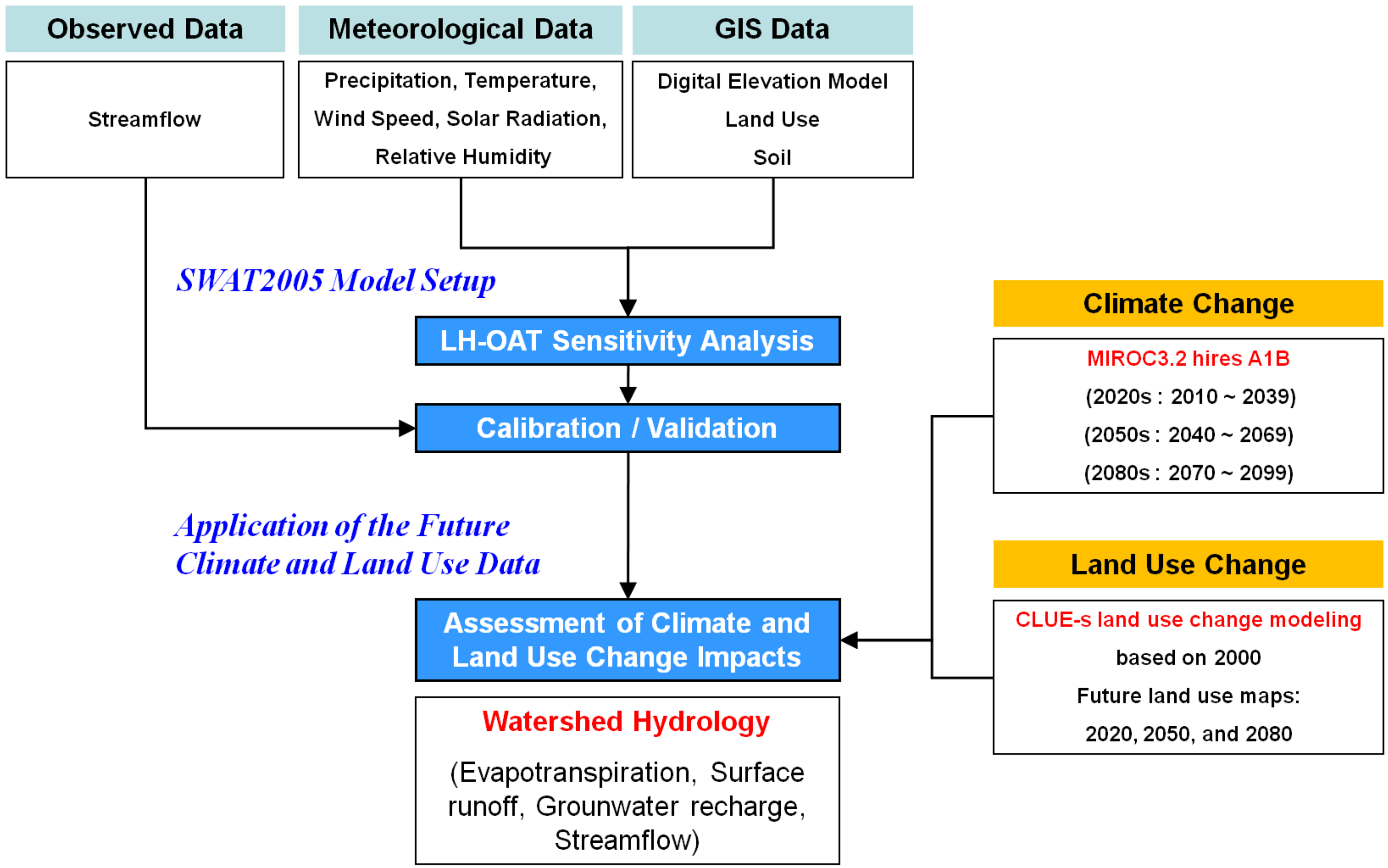
- **Climate change** affects the hydrological cycle, thus modifying the transformation and transport characteristics of sediment and nutrients.

- For the adaptation due to climate change as a fixed fact in the future, watershed decision makers require quantitative results for the establishment of strategy.

- **Land use** is the essential information in watershed hydrology.
  - ✓ The effects of land use are directly linked to changes hydrologic components in watershed such as evapotranspiration, surface runoff, groundwater, and streamflow.

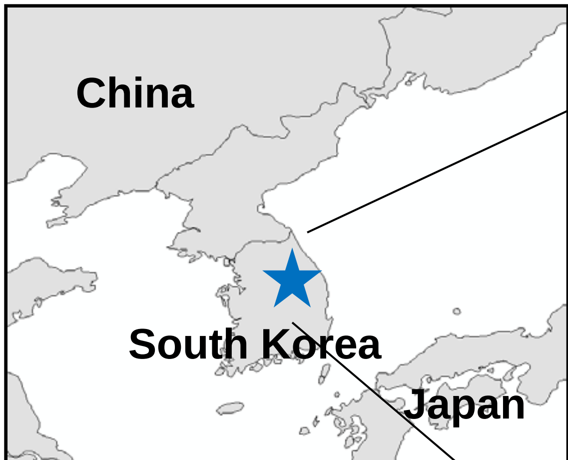
- This study is to evaluate the future potential climate and land use change impacts on watershed hydrology for a 6,642.0 km^2 dam watershed of South Korea.

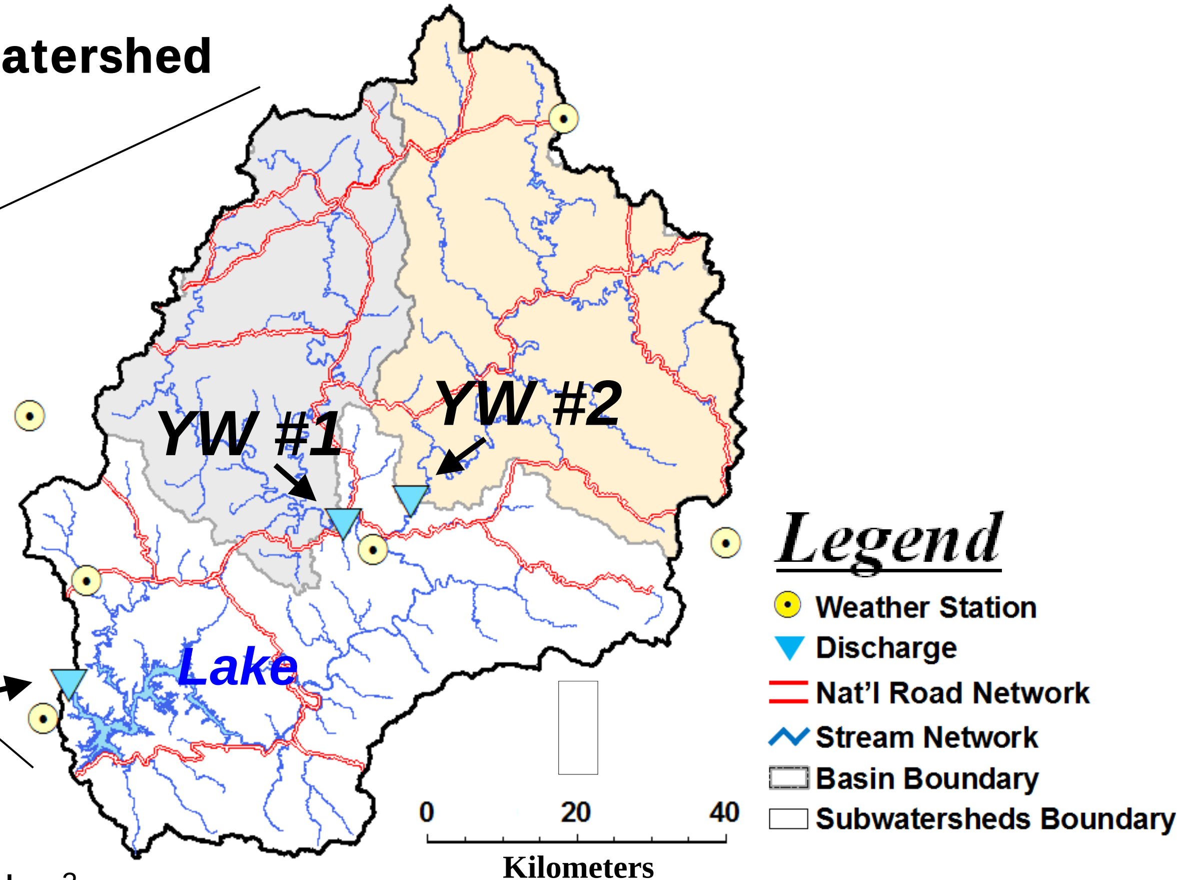
Study Procedure



Study Area

◆ **Chungjudam study watershed**





- ✓ Watershed area : 6,642.0 km^2
- ✓ Annual average precipitation : 1,359.5 mm
- ✓ Annual average temperature : 9.4 ℃
- ✓ Forest area : 82.3 % (5573.1 km^2)

Preparation of input data

Data set for SWAT model

Data Set	Source	Scale	Data Description / Properties
Terrain	Korea National Geography Institute	1/5,000	Digital Elevation Model (DEM) ; 100 X 100 m
Soil	Korea Rural Development Administration	1/25,000	Soil classifications and physical properties such as bulk density, texture, and saturated conductivity.
Land use	Landsat TM Satellite Image in 2000	30 m	Land use classifications such as paddy, grass, and forest.
Weather	Korea Meteorological Administration	Daily	Precipitation, minimum and maximum temperature, mean wind speed and relative humidity data from 1995 to 2006
Streamflow	Han River Flood Control Office	Daily	Streamflow data from three gauging stations

Preparation of input data

Data set for CLUE-s model

Data Set		Description
Spatial	Land use map	6 Landsat land uses (1975, 1980, 1985, 1990, 1995, and 2000) of 5 classes (water, bare field, grass, forest, and agriculture)
	Driving factors	11 driving factors were evaluated by following stepwise logistics regression
	Area restrictions (option)	Such as the nature reserve area
Non-spatial	Land requirements	For each year of the simulation these requirements determine the total area of each land use type that needs to be allocated by the model
	Spatial policies (option)	This option indicates areas where land use changes are restricted through spatial (land use) policies or tenure status
	Conversion elasticity	The conversion elasticity is one the land use type specific setting that determine the temporal dynamics of the simulation
	Land use conversion sequences	Not all land use changes are possible and some land use changes are very unlikely

SWAT Hydrological Model

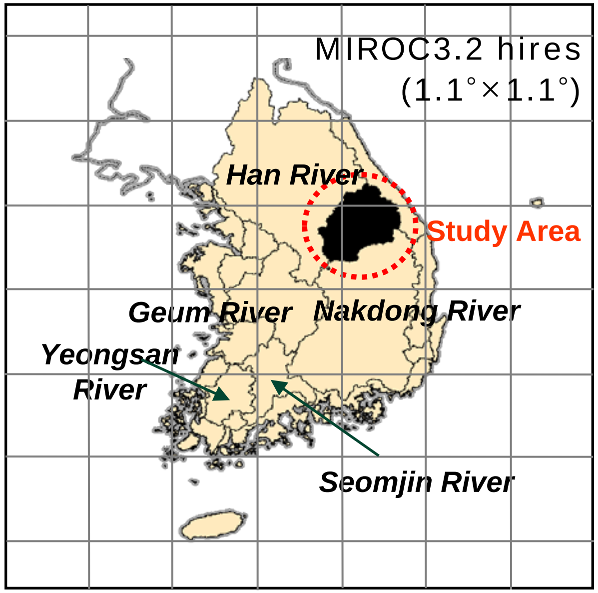
- **Soil and Water Assessment Tool** (Arnold et al., 1998)
  - ✓ SWAT is a continuous, long-term, and distributed-parameter model designed to predict the impact of land management practices on the hydrology and sediment and contaminant transport in agricultural watersheds.
  - ✓ SWAT subdivides a watershed into sub-basin connected by a stream network, and further delineates HRUs (Hydrologic Response Unit) consisting of unique combinations of land cover and soils within each sub-basin.
  - ✓ The hydrological cycle as simulated by SWAT is based on the water balance equation:

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

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)

General Circulation Models (GCMs)

◆ Future Climate Data from GCMs (MIROC3.2 hires)



Model	MIROC3.2 hires
Center	NIES (National Institute for Environmental Studies)
Country	Japan
Scenario	A1B, B1
Grid size	1.125° × 1.125°

- ✓ The GCM (MIROC3.2 hires) data by two SRES climate change scenarios of the IPCC AR4 (fourth assessment report) were adopted.
- ✓ The MIROC3.2 hires model, developed at the NIES of the Japan, had the highest spatial resolution of approximately 1.1° among the selected model in IPCC AR4.

Downscaling Technique of GCM Data

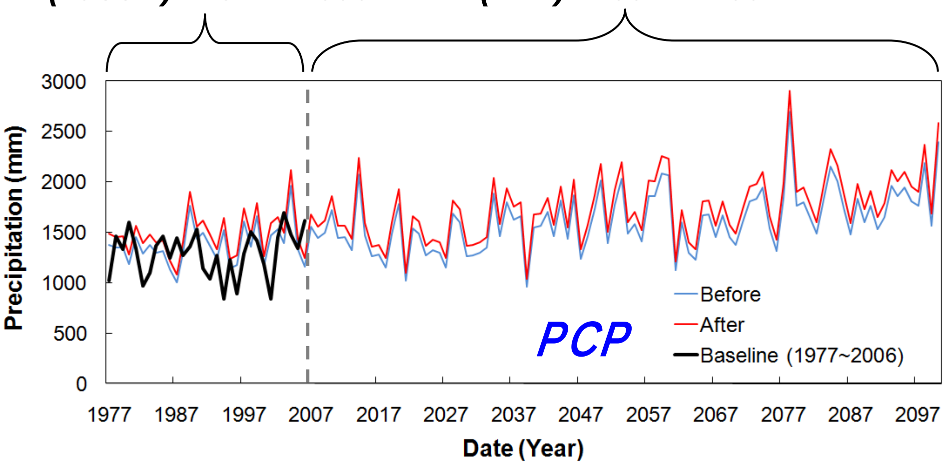
- **Bias correction method** (Sharma et al. 2007; Hansen et al. 2006)
  - ✓ The GCM data was corrected to ensure that 30 years observed data (1977-2006, baseline period).
  - ✓ GCM model output of the same period have similar statistical properties among the various statistical transformations.

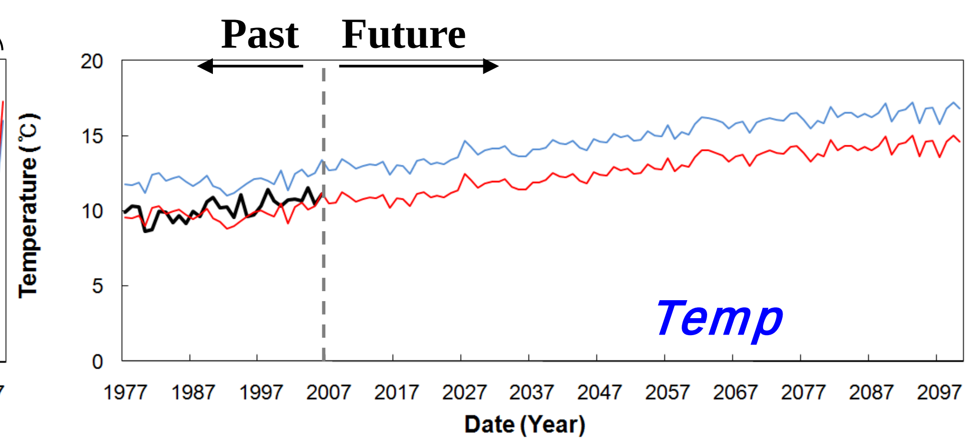
For precipitation $P'_{GCM,\,fut} = P_{meas} \times (\overline{P}_{GCM,\,fut} \div \overline{P}_{GCM,\,his})$ ⇨ **Factor: 1.08**

For temperature $T'_{GCM,\,fut} = T_{meas} + (\overline{T}_{GCM,\,fut} - \overline{T}_{GCM,\,his})$ ⇨ **Factor: -2.20**

20th Century Simulations (20C3M) : 1977 - 2006

21th Century Simulations (A1B) : 2007 - 2100



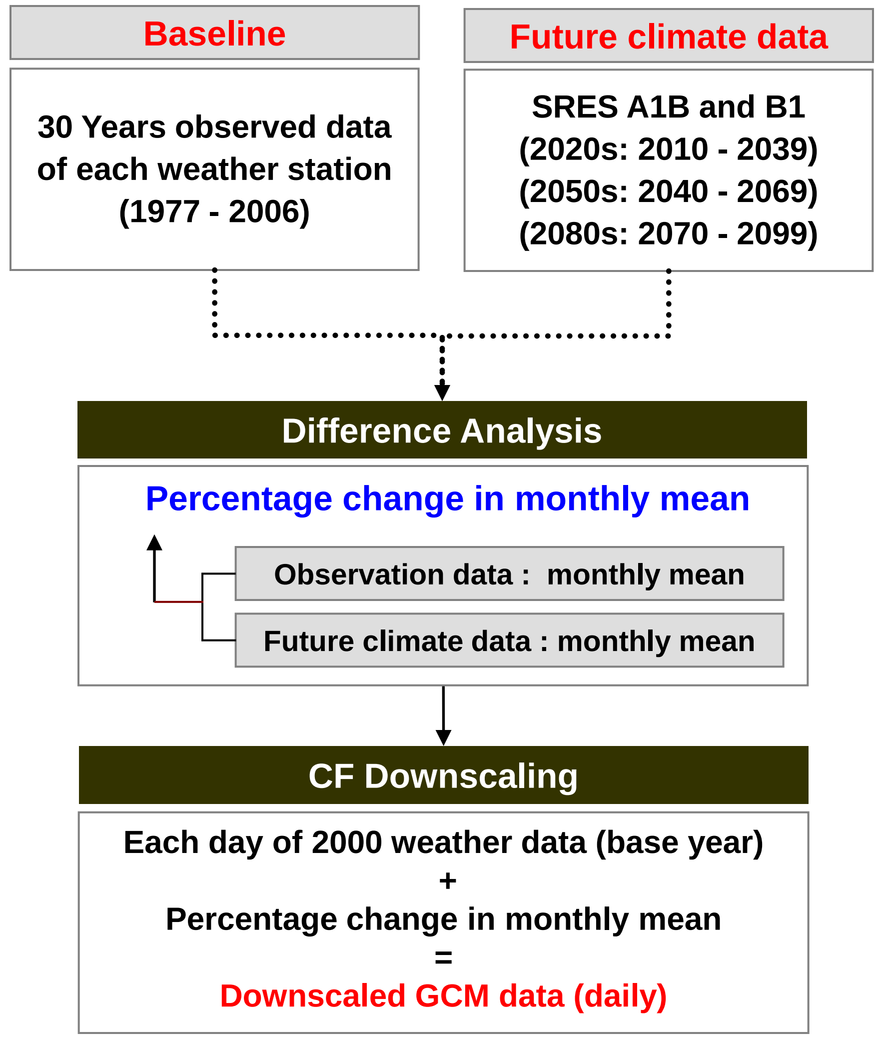


Downscaling Technique of GCM Data

◆ Change Factor (CF) method

(Alcamo et al. 1997; Droogers and Aerts 2006)

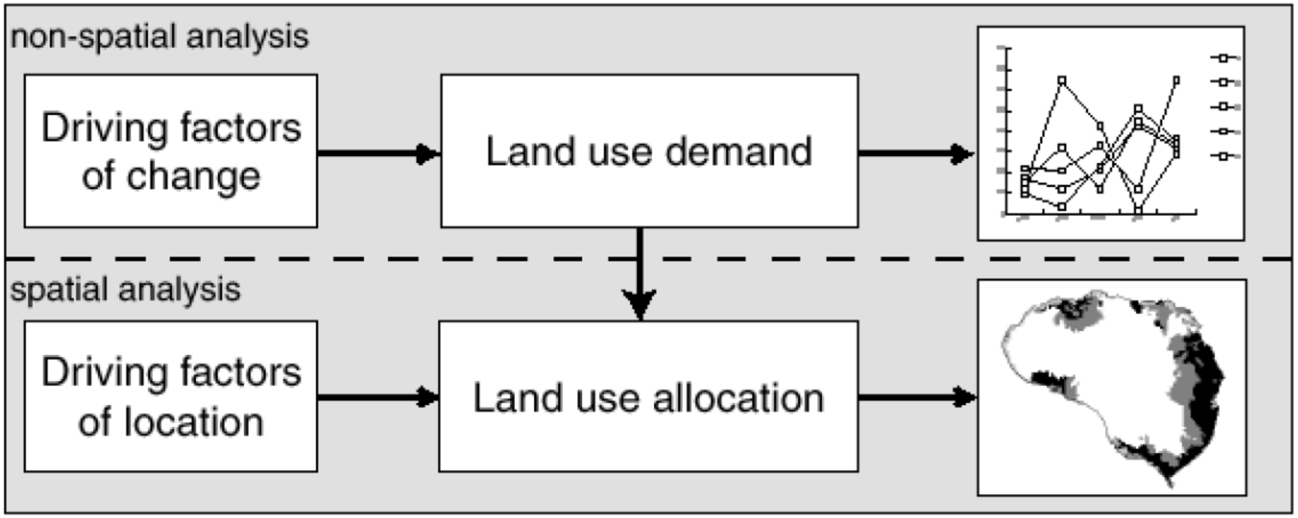
- ✓ GCM model was downscaled using Change factor (CF) method.
- ✓ Monthly mean changes in equivalent variables from the 30 years data (1977-2006, baseline period) and three GCM simulations for three time periods: 2020s, 2050s and 2080s were calculated for the GCM grid cell.
- ✓ The percentage changes in monthly mean were applied to each day of **2000** weather data (base year for future assessment) of each weather station.



Land Use Change Model

CLUE-s land use change model (Veldkamp and Fresco 1996; Verburg et al. 1999)

- ✓ The Conversion of Land Use and its Effects at Small regional extent (CLUE-s) was developed to simulate land use change.
- ✓ The model is subdivided into two distinct modules, namely a non-spatial demand module and a spatially explicit allocation procedure.
  - The non-spatial module calculates the area change for all land use types
  - The spatial module are translated into land use changes at different locations within the study region



Land Use Change Model

Driving factors

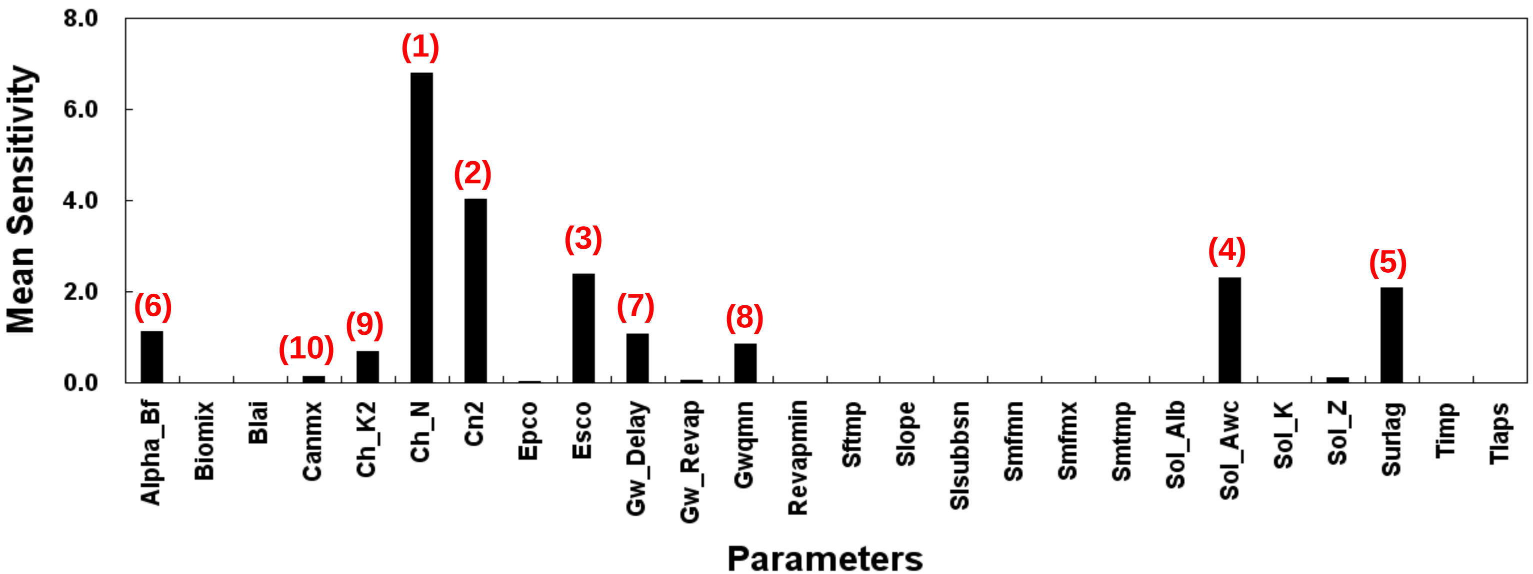
- ✓ The probability maps of each land use type were prepared from the logistic regression results.
- ✓ The forward stepwise logistics regression and relative operating characteristics (ROC) analyses between 5 land use types and 11 driving factors.

Driving factor	Land use type				
	Urban	Bare field	Grass	Forest	Agriculture
Altitude	−	0.0014	0.0010	0.0019	0.0007
Slope	−	−	−	0.0081	−
Aspect	−	- 0.0024	−	- 0.0006	−
Distance to national road	- 0.0003	- 0.0001	- 0.0001	- 0.0001	- 0.0002
Distance to local road	−	−	−	0.0002	−
Distance to city	- 0.0001	−	- 4.0E-05	0.0001	−
Distance to stream	- 0.0004	−	−	4.0E-05	−
Soil drainage class	−	−	−	- 0.1256	- 0.0960
Soil type	−	−	0.1100	0.0774	−
Soil depth	−	−	−	- 0.0027	−
Land use in the soil	−	−	−	- 0.0346	−
Constant	- 3.5653	- 5.2972	- 4.800	- 1.6195	- 2.2253
ROC	0.734	0.748	0.602	0.778	0.646

−: not significant at 0.05 significant level, thus excluded in model

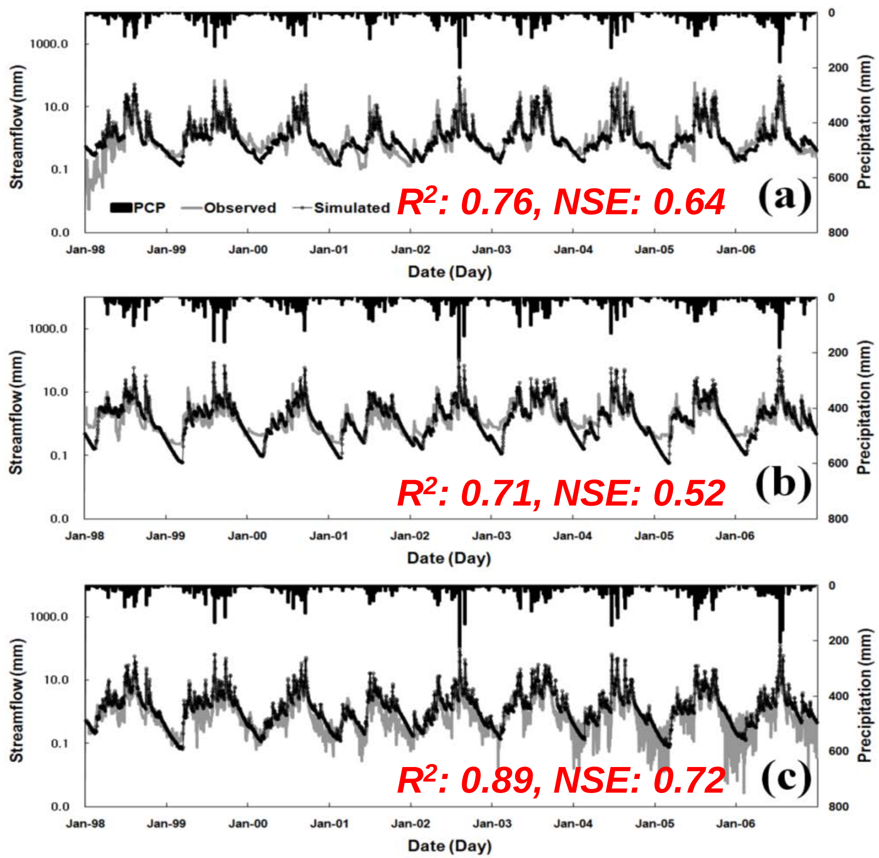
Sensitivity Analysis (SA)

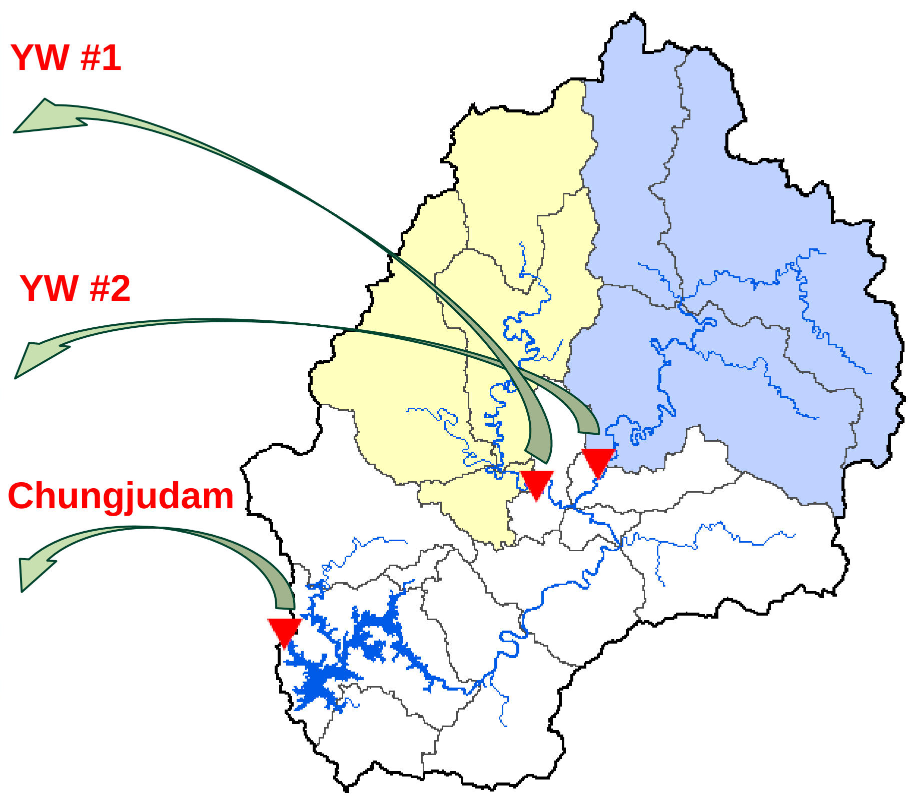
- **Latin Hypercube (LH) – One-factor-At-a-Time (OAT)**
  - ✓ A parameter **SA** provides insights on which parameters contribute most to the output variance due to input variability. In this study, we performed an **LH-OAT** SA.
  - ✓ The SA was performed for 26 parameters of hydrology that may have a potential to influence hydrologic components.
  - ✓ Using the SA results calibrated parameters for hydrology.



SWAT Calibration and Validation

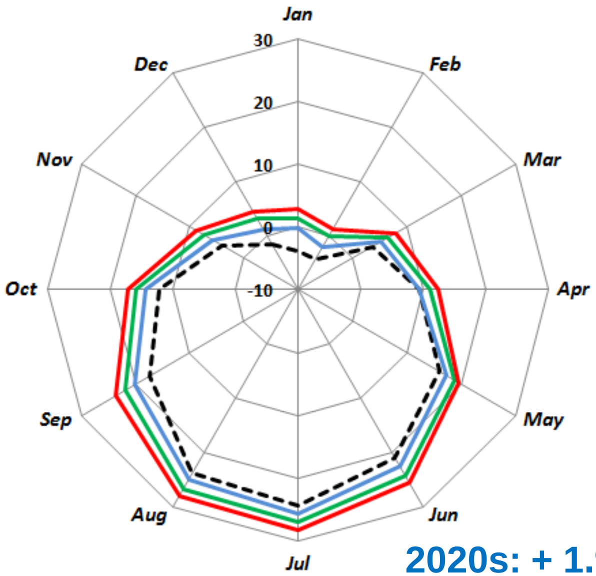
- **Streamflow**
  - ✓ Calibration period : 1998-2000 / Validation period : 2001-2003
  - ✓ Using daily discharge records at three calibration points





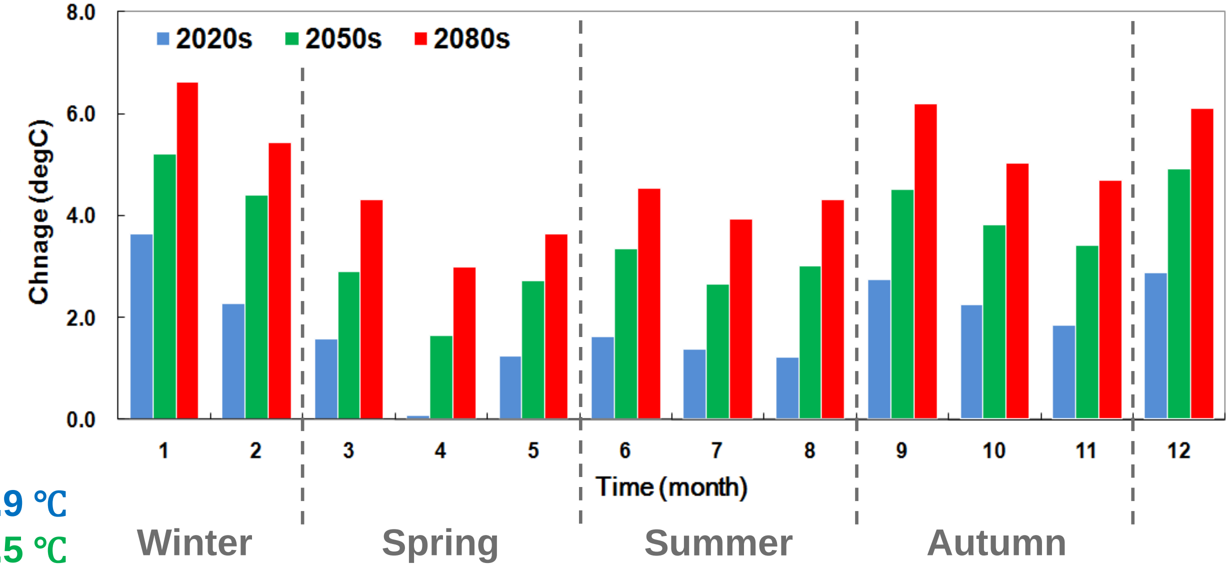
Climate Change Scenario

- **Future climate data by applying CF downscaling method**
  - ✓ Temperature change



2020s: + 1.9 ℃
2050s: + 3.5 ℃
2080s: + 4.8 ℃

Temperature change (℃)

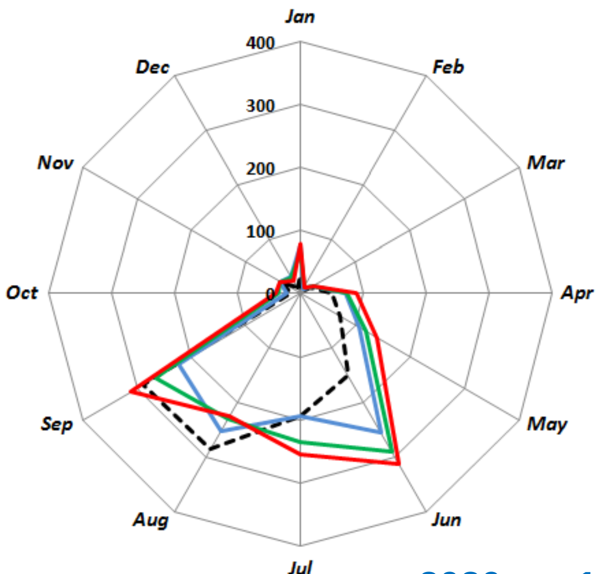


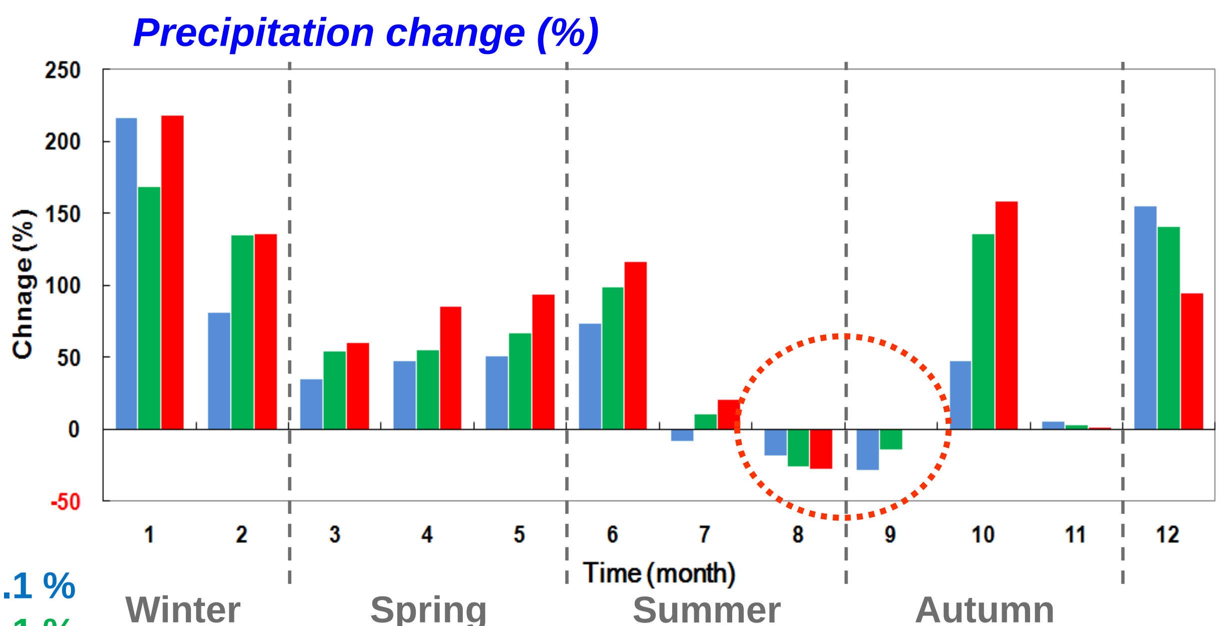
- ✓ The future temperature will give warming for the whole season from results of CF downscaling. Especially, the seasonal temperature change is that the intensity of big increase is found in Winter.

Climate Change Scenario

Future climate data by applying CF downscaling method

✓ Precipitation change



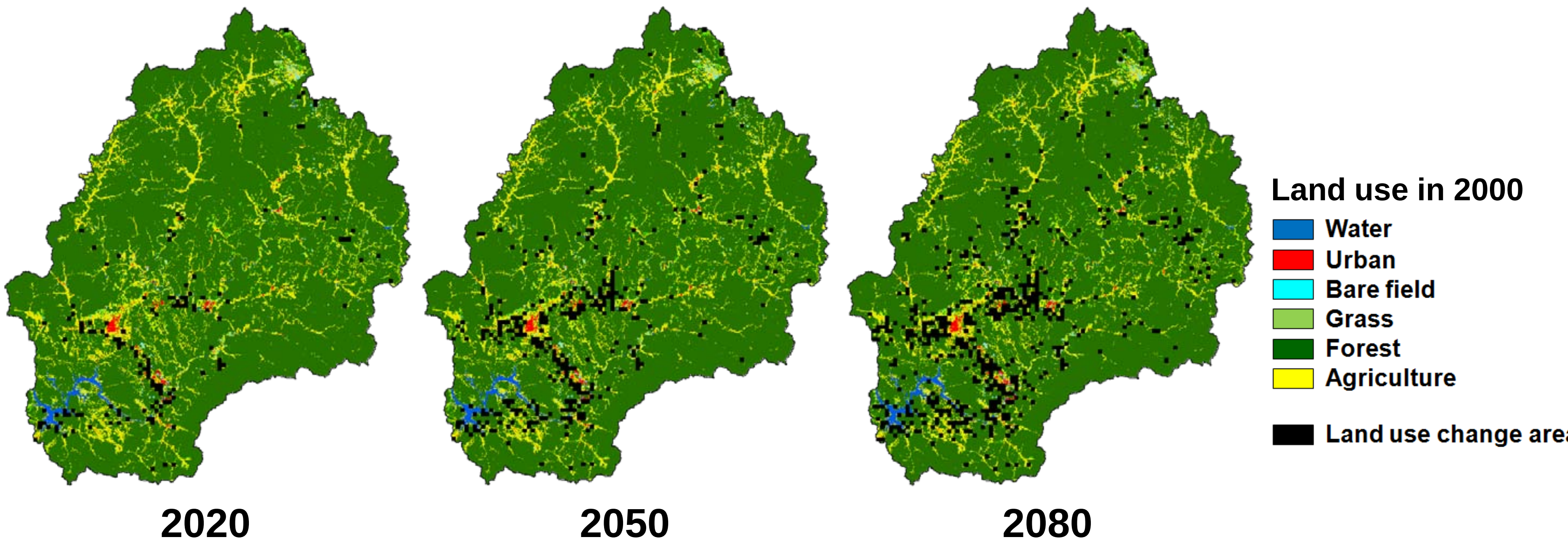


2020s: + 17.1 %
2050s: + 23.1 %
2080s: + 34.4 %

✓ The future precipitation showed general tendency of decrease for August and September. Other months showed the increase tendency on the whole.

Land Use Change Scenario

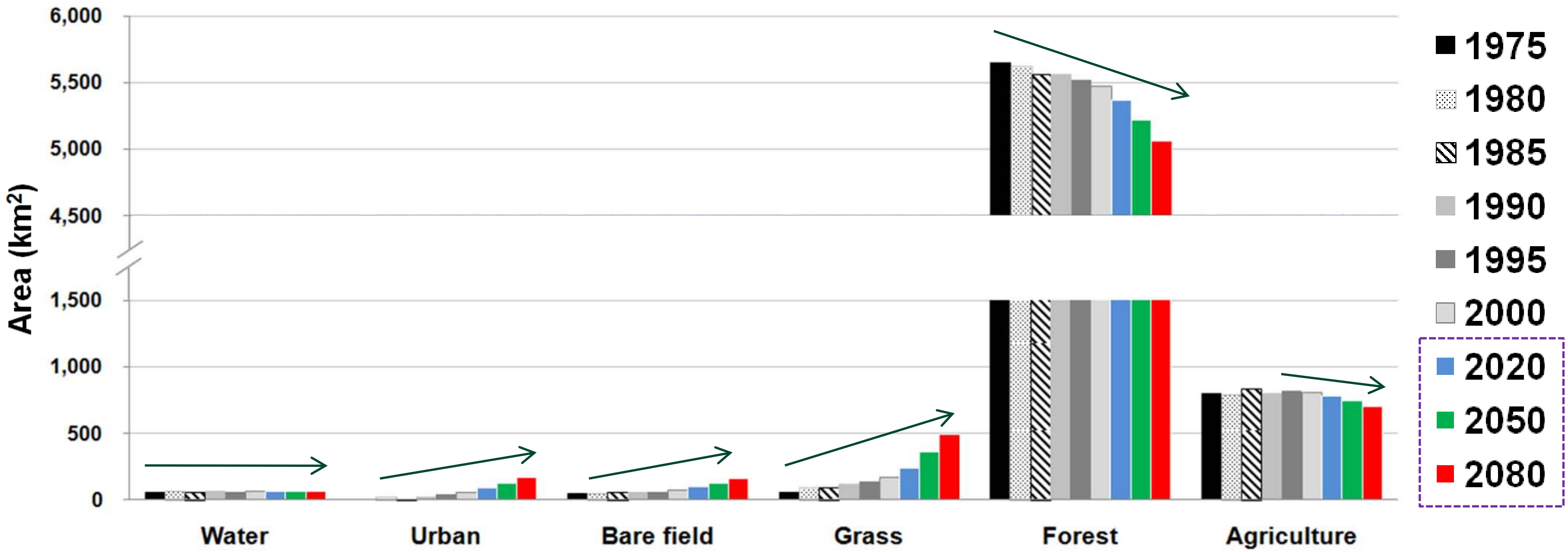
◆ Land use change areas in the future based on 2000



- ✓ By applying the derived regression models and the prepared land uses, the future land uses of 2020, 2050, and 2080 were predicted.
- ✓ The most changed areas were occurred around lake of Chungjudam, and near the urban area.

Land Use Change Scenario

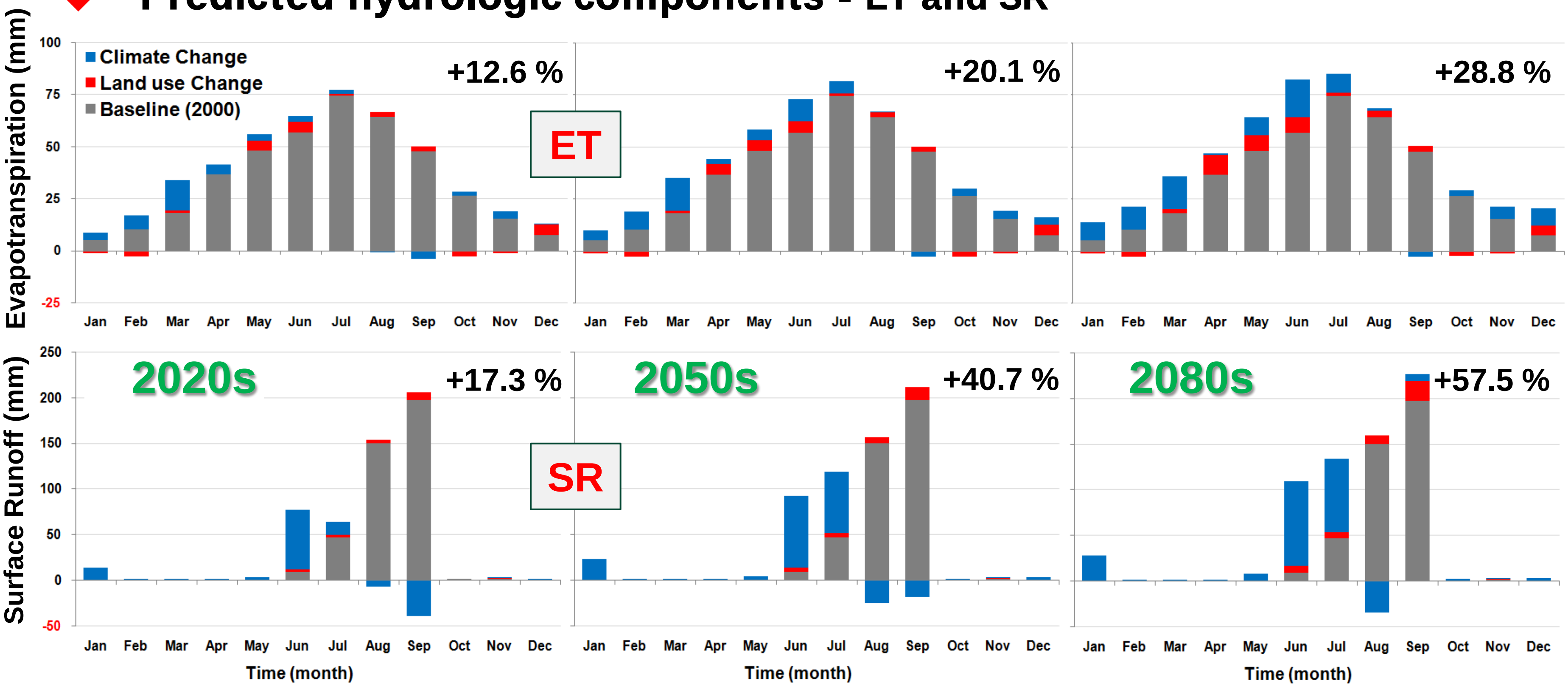
◆ **Future predicted land use by CLUE-s**



- ✓ The 2080 forest and agriculture decreased 6.2 % and 1.6 % based on 2000. Meanwhile, the urban, bare field, and grass increased 1.7 %, 1.3 %, and 4.8 % respectively in 2080.
- ✓ The big increase of grass was come from the steady construction of pasture during 1970s and 1980s and golf courses in 1990s within the watershed.

Future Impact on Watershed Hydrology

- **Predicted hydrologic components - ET and SR**

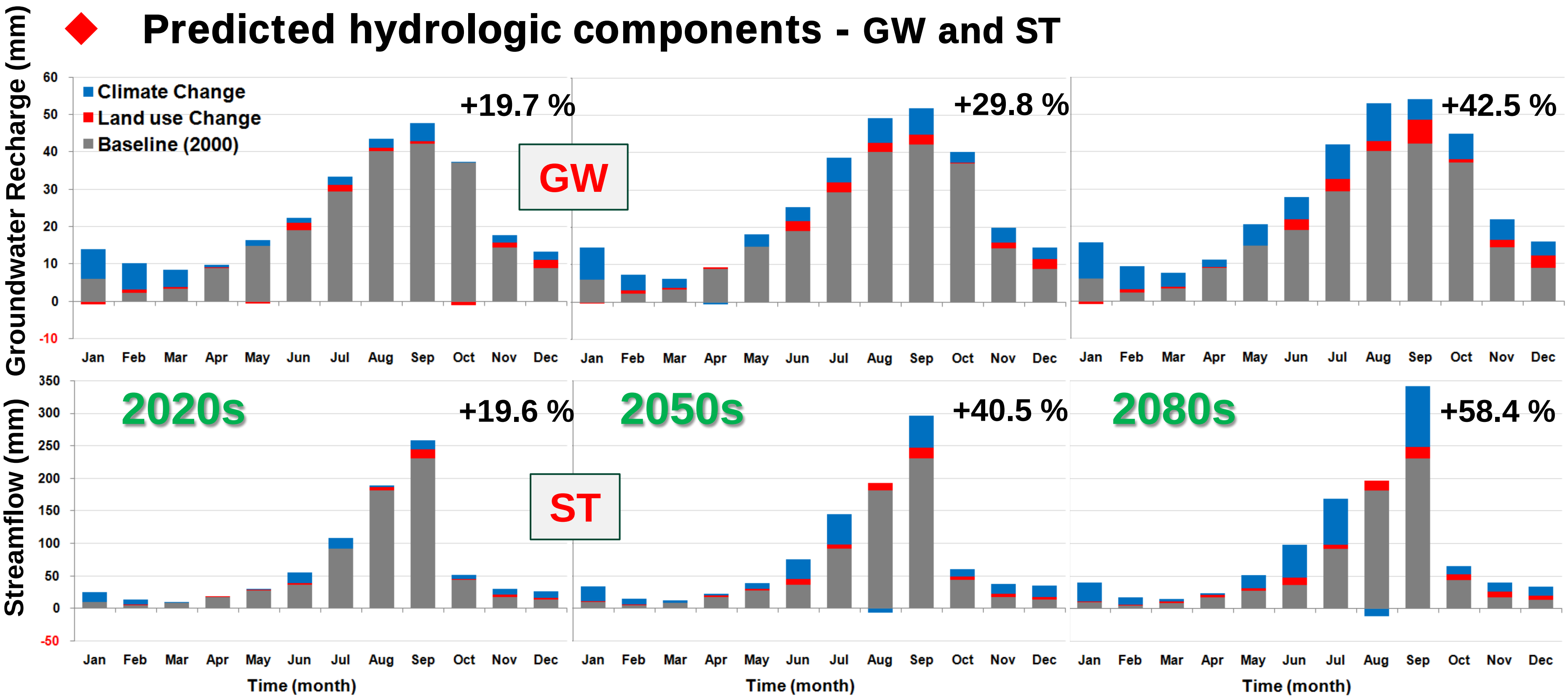


✓ The future annual ET increased in all scenarios, especially showing big increases in Mar, May and June.

✓ Surface runoff was predicted to change between + 17.3 % ~ + 57.7 % depend on precipitation, especially showing big increase in June.

Future Impact on Watershed Hydrology

- Predicted hydrologic components - GW and ST



✓ The future GW and ST were more affected by the land use change compared to the ET and SR. Annual GW and ST increased gradually going by the future.

✓ The changes will also affect the dam operation rule of Aug. and Sep. flood control, and reservoir water level management of Oct.

Concluding Remarks

- The future **climate data of the MIROC3.2 hires** showed that temperature increased in four seasons, and precipitation increased in summer, but decreased in autumn.
- The future **land use of the CLUE-s** showed that forest and agriculture decreased 6.2 % and 1.6 % in 2080 based on 2000. Meanwhile, the urban, bare filed, and grass increased 1.7 %, 1.3 %, and 4.8 % in 2080.
- By applying the future MIROC3.2 downscaled climate and CLUE-s land use conditions, the SWAT was run to evaluate the future watershed impact on hydrologic components viz. ET, SR, GW and ST.
  - ✓ The future ET was mostly affected by the climate change than land use change. SR were mostly affected by the climate change than land use change.
  - ✓ The 2080s ST and GW showed + 39.8 %, + 28.1 % by climate change only while + 58.4 %, + 59.4 % change by climate plus land use changes scenario.
  - ✓ Climate change impact on watershed hydrology is more sensitive than land use change.
- <u>Groundwater resources will become more important in the future.</u>

Concluding Remarks

- We need efforts to sustain the groundwater resources by the proper soil and land cover conservation practice, and the integrated watershed management to secure stable streamflow.

- The future monthly dam inflow change gave us the clue for the future adjustment of dam operation rule for both efficient water use and flood control.

- The future hydrologic components cannot be projected exactly due to the uncertainty in climate and land use change scenarios and models outputs (GCM, SWAT, CLUE-s).

- The annual change and seasonal variation of hydrologic components due to future temperature increase and precipitation and land use change should be evaluated 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.

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Thank You

http://msyouth.blogspot.com/2008/04/global-warming-videos.html