Analysis of the Future Climate Change Impact on Vegetation Canopy and Growth Period

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Min-Ji Park, Hyung-Jin Shin, In-Kyun Jung, Gean-Ae Park
Post-doctoral researcher

Mi-Seon Lee
Research Fellow

Seong-Joon Kim
Professor

Dept. of Civil & Environmental System Eng.
Konkuk University, South Korea

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  - SWAT model
  - Data preparation for future climate change impact
  - Impact of rising climate and CO_2 on vegetation canopy and growth periods
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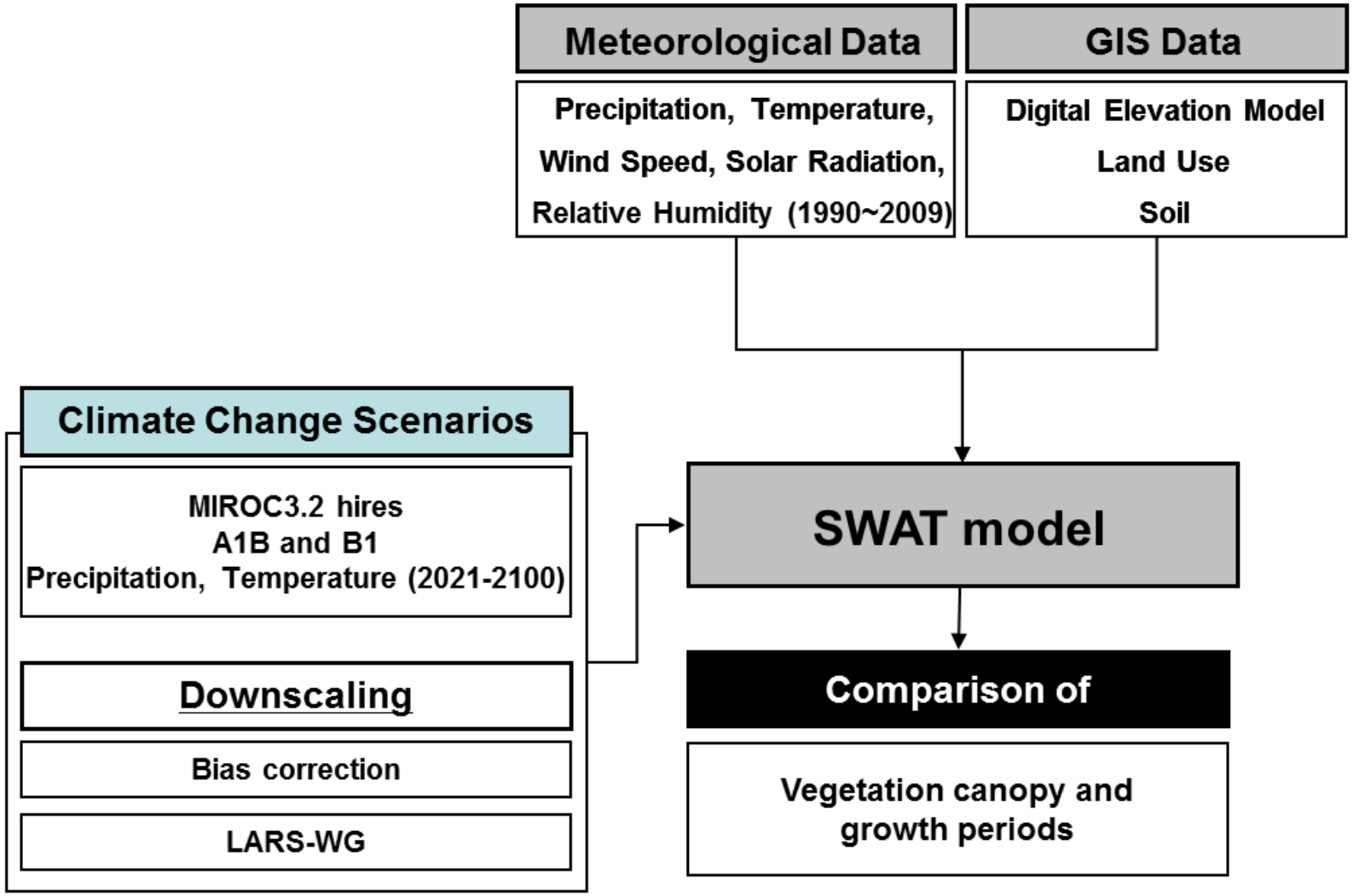
Introduction

- Climate change can impact the geographical dispersal and growth of different plants around the world.
- Leaf Area Index (LAI) is the ratio of total upper leaf surface of vegetation divided by the surface area of the land on which the vegetation grows.
- LAI is used to calculate the evapotranspiration and eventually affects water characteristics such as stream volume and flow, ground water levels and quality.
- The main goal of this study is to predict LAI by GCM scenarios and identify the change as a result of future rising temperature and CO_2 using SWAT.

Flow chart


Meteorological Data
Precipitation, Temperature,
Wind Speed, Solar Radiation,
Relative Humidity (1990~2009)
GIS Data
Digital Elevation Model
Land Use
Soil
Climate Change Scenarios
MIROC3.2 hires
A1B and B1
Precipitation, Temperature (2021-2100)
Downscaling
Bias correction
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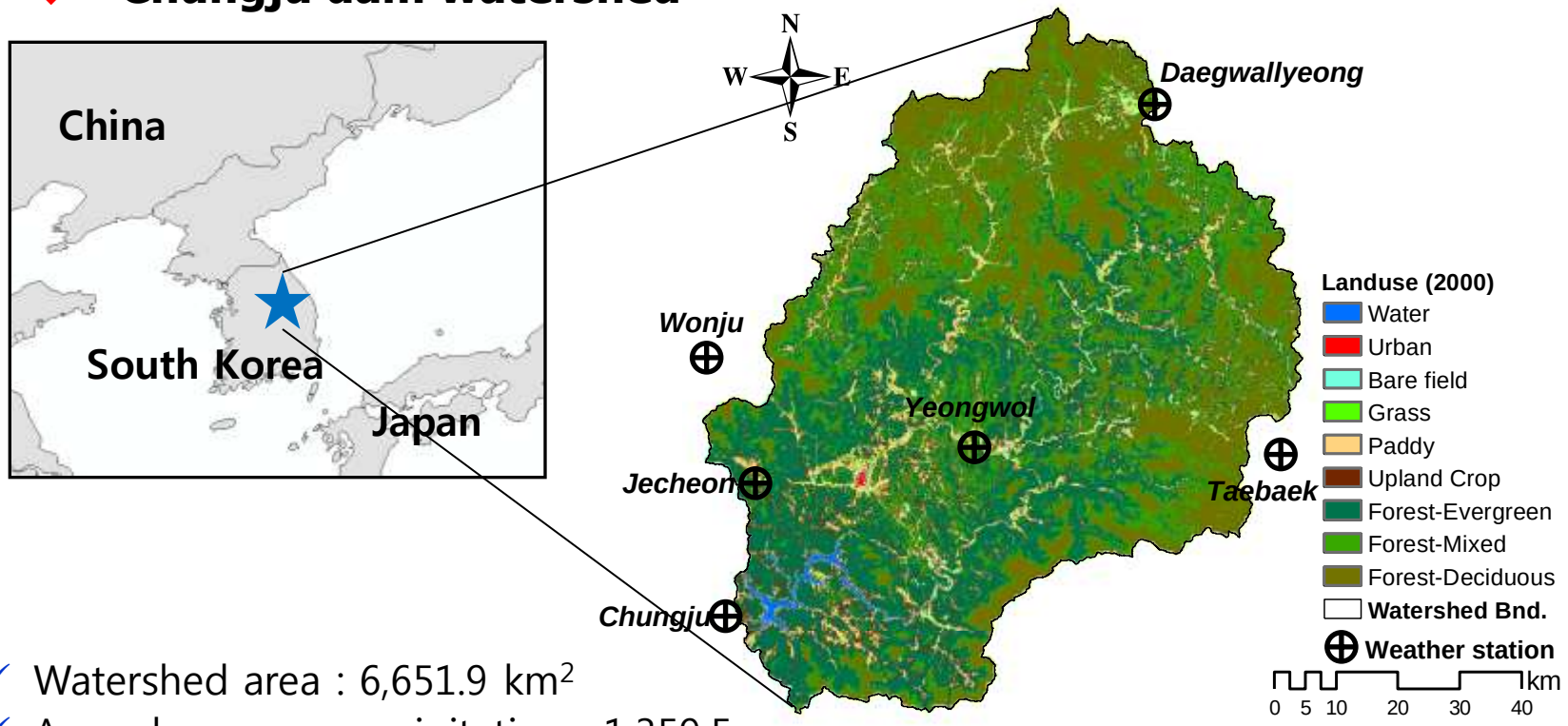
Comparison of
Vegetation canopy and
growth periods

Study watershed

- **Chungju dam watershed**



- ✓ Watershed area : 6,651.9 km^2
- ✓ Annual average precipitation : 1,359.5 mm
- ✓ Annual average temperature : 9.4 ℃
- ✓ Forest area : 82.8 % of the study area (5,509.2 km^2)
- ✓ Vegetation covered area: 97.2 % (6,468.3 km^2)
- ✓ Latitude range : 36.8 °N ~ 37.8 °N
- ✓ Longitude range : 127.9 °E ~ 129.0 °E

Study watershed

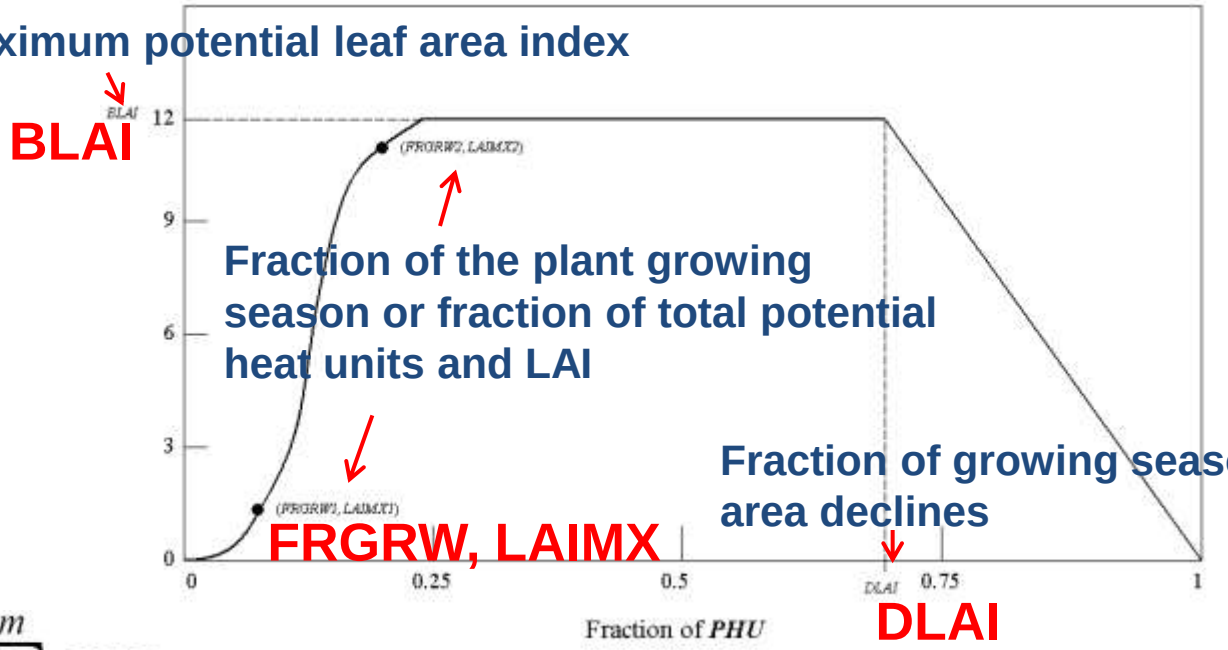
Drought and flood damages in South Korea are frequent during spring and summer periods respectively.

The Chungju Dam, a multipurpose dam and the largest water project in South Korea, was constructed in the South Han river, which meanders through the central region of the Korean peninsula. The dam's main functions are water supply and flood control.

The Chungju Dam now plays a vital role in drought and flood reduction in South Korea capital region.

SWAT Model description

- **Leaf area index as a function of fraction of growing season for Alamo switchgrass**



$$PHU = \sum_{d=1}^{m} HU$$

HU: The number of heat units accumulated on a given day (heat units)
PHU: The total heat units required for plant maturity (heat units)

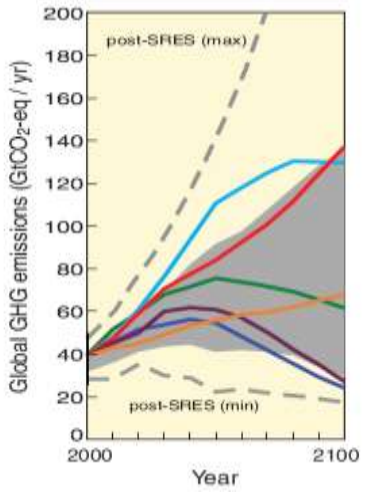
Model setup

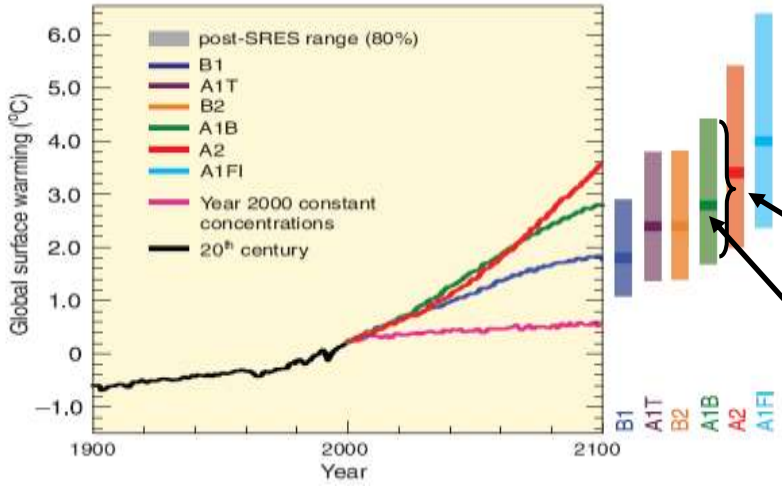
❖ Data set for SWAT model

Data Type	Source	Scale	Data Description / Properties
Terrain	National Geography Institute	1/5,000	Digital Elevation Model (DEM)
Soil	Rural Development Administration	1/25,000	Soil classifications and physical properties viz. texture, porosity, field capacity, wilting point, saturated conductivity, and soil depth
Land Use	Water Management Information System	30 m	Landsat land use classification (2000 year, 9 classes)
Weather	Meteorological Administration	-	Daily precipitation, minimum and maximum temperatures, mean wind speed and relative humidity data of **6 stations** from 1977 to 2009

Climate Change Scenarios

❖ Special Report on Emission Scenarios (SRES)





2100 year

A2 (high)	**→ CO_2 830 ppm**
A1B (middle)	**→ CO_2 720 ppm**
B1 (low)	**→ CO_2 550 ppm**

'Likely range'

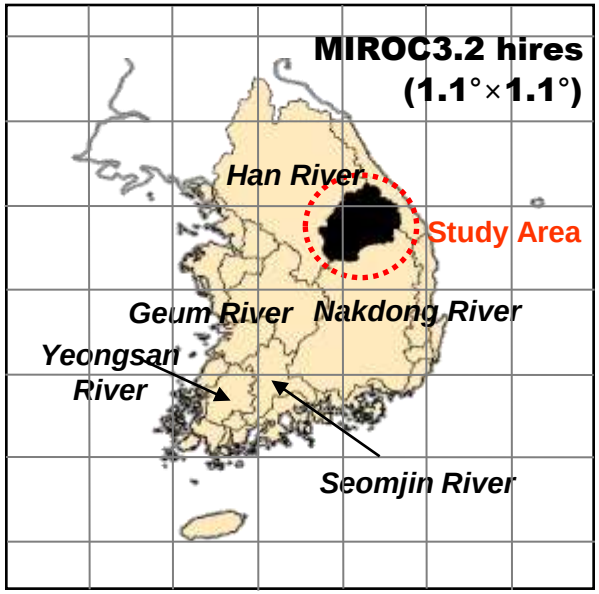
'Best estimate'

✓ In this study, GHG emission scenario adopted SRES "A1B" (warming middle) and "B1" (warming low) scenarios.

✓ **A1B** : A future world of very rapid economic growth, low population growth and rapid introduction of new and more efficient technology.
B1 : A very heterogeneous world. The underlying theme is that of strengthening regional cultural identities, with an emphasis on family values and local traditions, high population growth, and less concern for rapid economic development.

General Circulation Models (GCMs)

❖ Climate Data from GCM (MIROC3.2 hires)



Model	MIROC3.2 hires
Center	NIES (National Institute for Environmental Studies)
Country	Japan
Scenario	A1B, B1
Grid size	320 × 160 (1.1° × 1.1°)

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

Error Correction

- **Bias Correction Method (Droogers and Aerts, 2005)**
  - The GCM data was corrected to ensure to include 30 years of observed data (1977-2006, baseline period).
  - GCM model outputs of the same period have similar statistical properties among the various statistical transformations.

For temperature

$$T'_{GCM,fut} = T_{GCM} + (\overline{T}_{meas,his} - \overline{T}_{GCM,his})$$

For precipitation

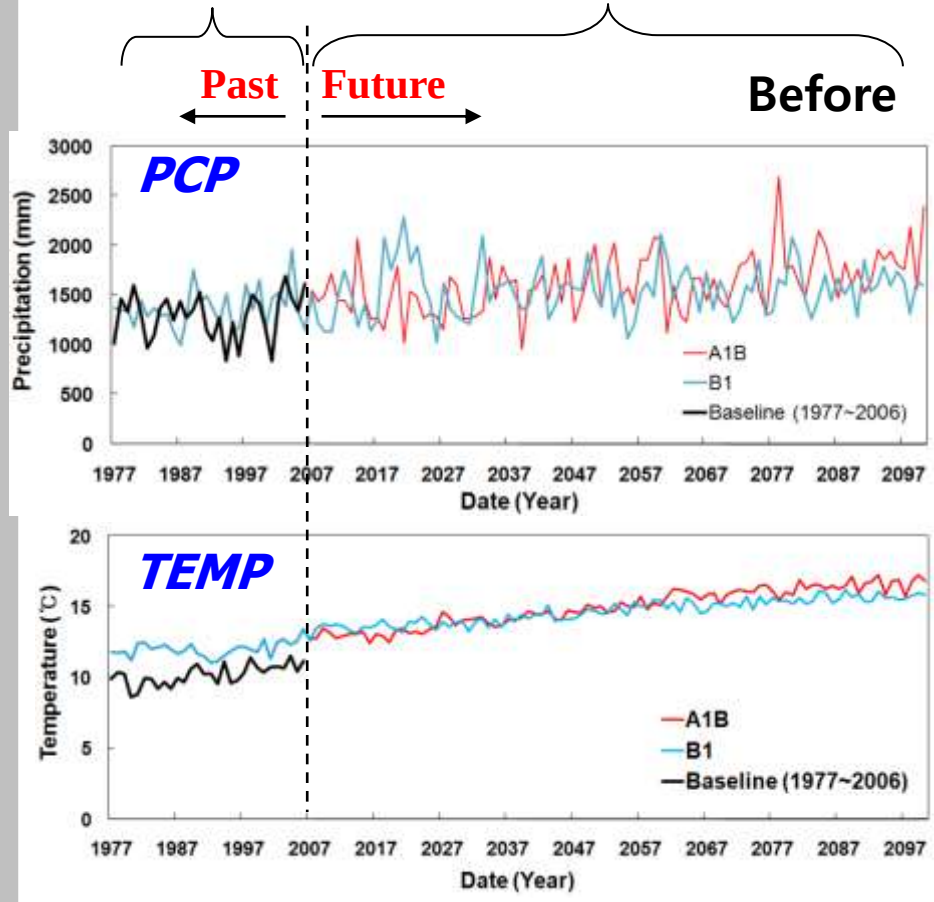
$$P'_{GCM,fut} = P_{GCM} \times (\overline{P}_{meas,his} / \overline{P}_{GCM,his})$$

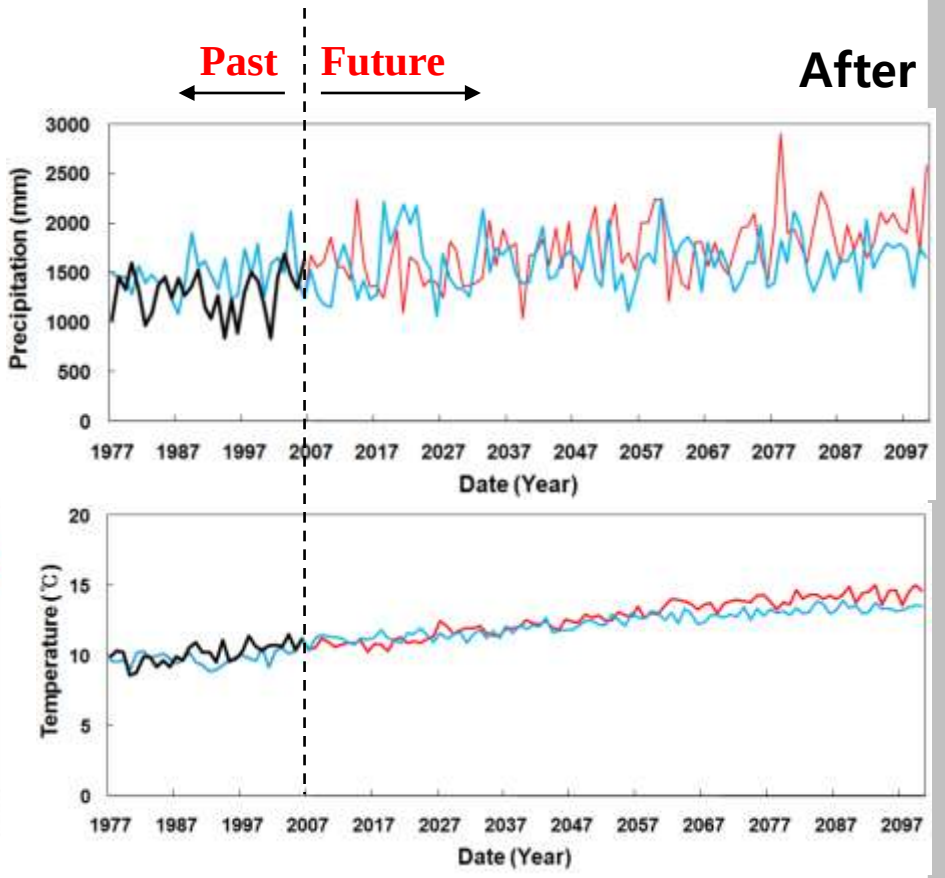
GCM	Scenario	Bias correction factor	
		Temperature	Precipitation
MIROC3.2 hires	A1B	-4.7 ~ - 0.7	0.89 ~ 1.45

Error Correction

20th Century Simulations (20C3M) : 1977 - 2000

21th Century Simulations (A1B and B1) : 2001 - 2100





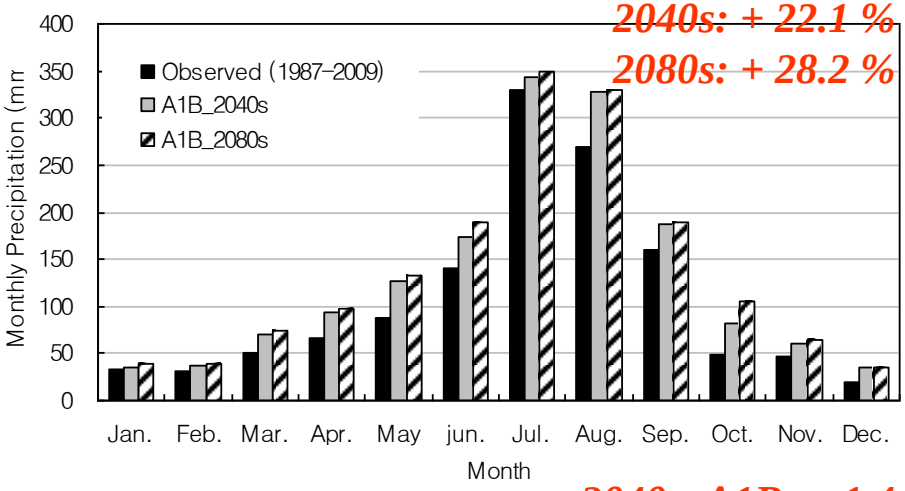
Downscaling

- **LARS-WG (Long Ashton Research Station – Weather Generator)**
  - A stochastic weather generator which can be used for the simulation of weather data at a single site under both current and future climate conditions.
  - Developed by Mikhail A. Semenov, 1997
  - Statistical downscaling
    - Empirical downscaling, employing statistical relationships between large-scale climatic state and local variations derived from historical data records.
    - Strengths: Cheap, computationally undemanding and readily transferable.
    - Weaknesses: Requires high quality data for model calibration, low-frequency climate variability problematic.
  - Precipitation (mm), maximum and minimum temperatures (°C) and solar radiation ($MJm^{-2}day^{-1}$).

Downscaling

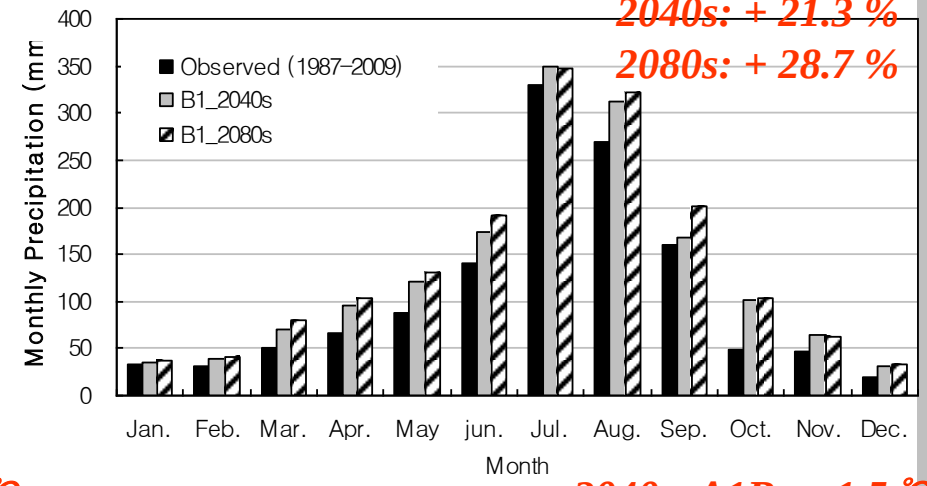
Precipitation (A1B)

2040s: + 22.1 %
2080s: + 28.2 %



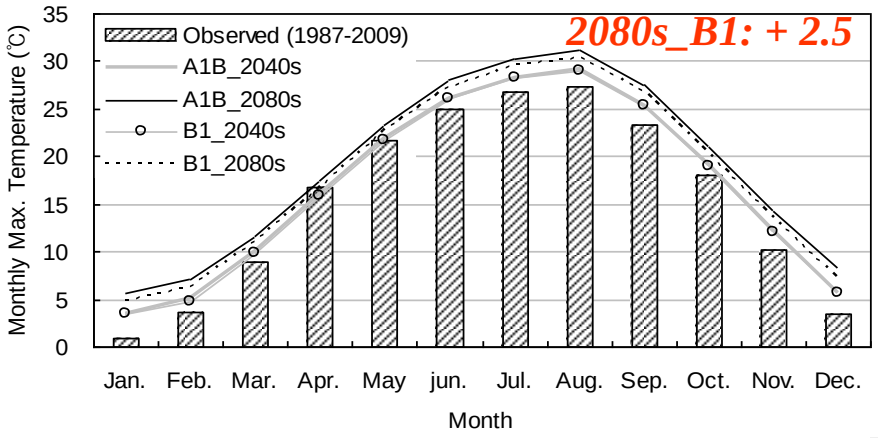
Precipitation (B1)

2040s: + 21.3 %
2080s: + 28.7 %



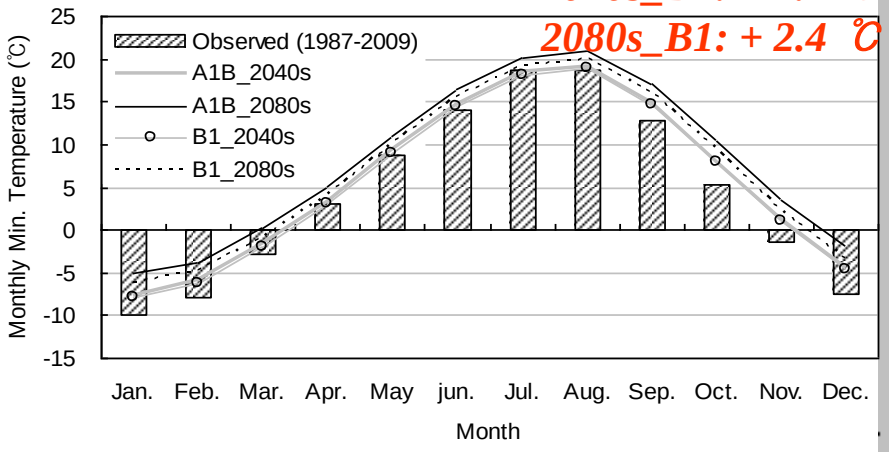
Maximum Temperature

2040s_A1B: + 1.4 ℃
2080s_A1B: + 3.3 ℃
2040s_B1: + 1.2 ℃
2080s_B1: + 2.5 ℃



Minimum Temperature

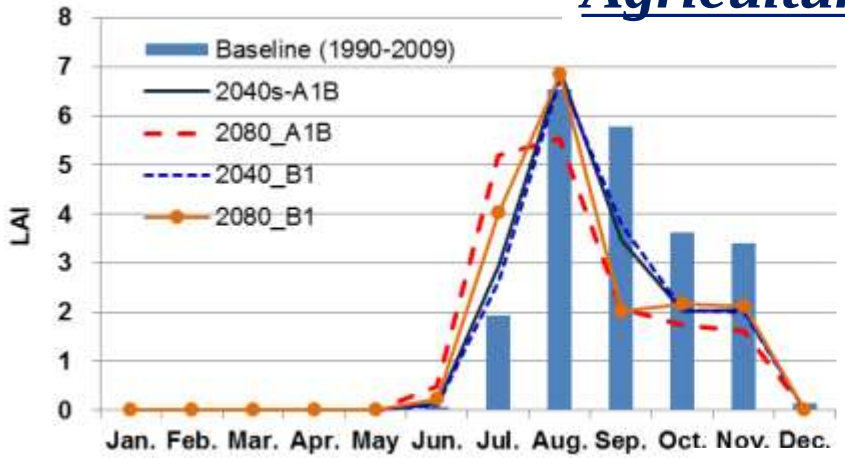
2040s_A1B: + 1.5 ℃
2080s_A1B: + 3.5 ℃
2040s_B1: + 1.2 ℃
2080s_B1: + 2.4 ℃



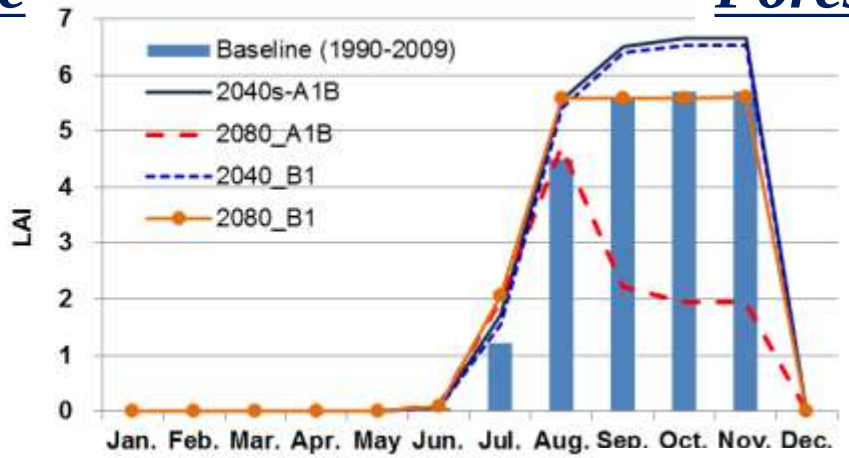
Results

- The change of monthly LAI in the 2040s and 2080s for A1B and B1 emission scenarios compared to the baseline (1990-2009)

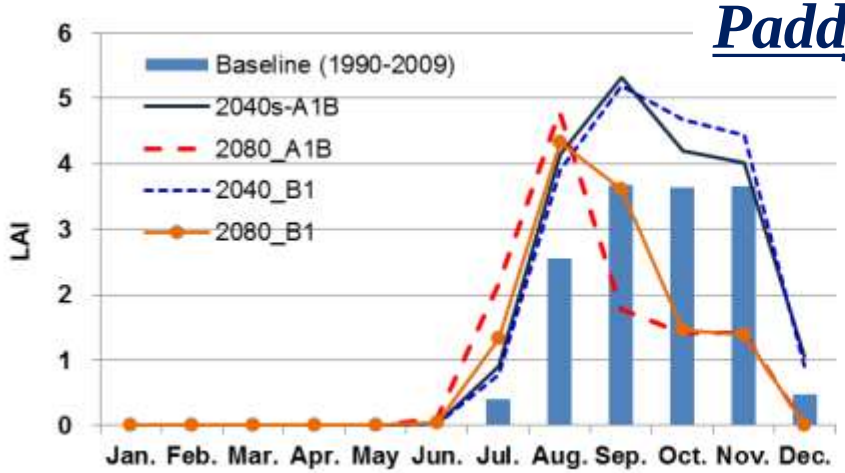
Agriculture



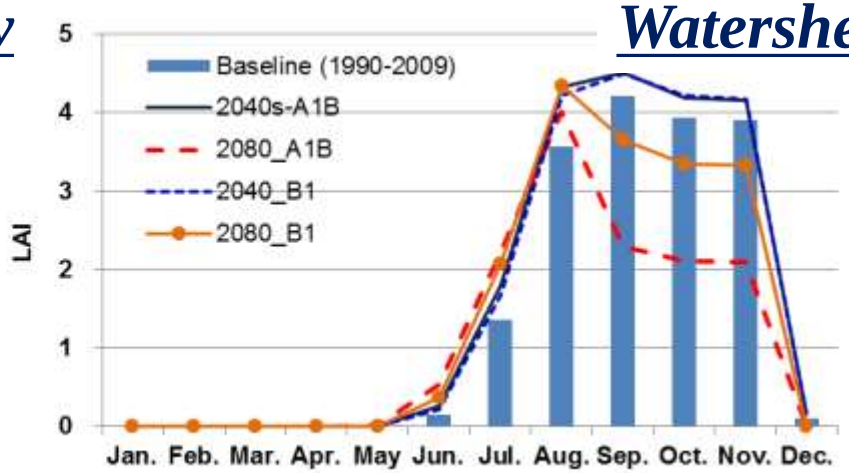
Forest



Paddy

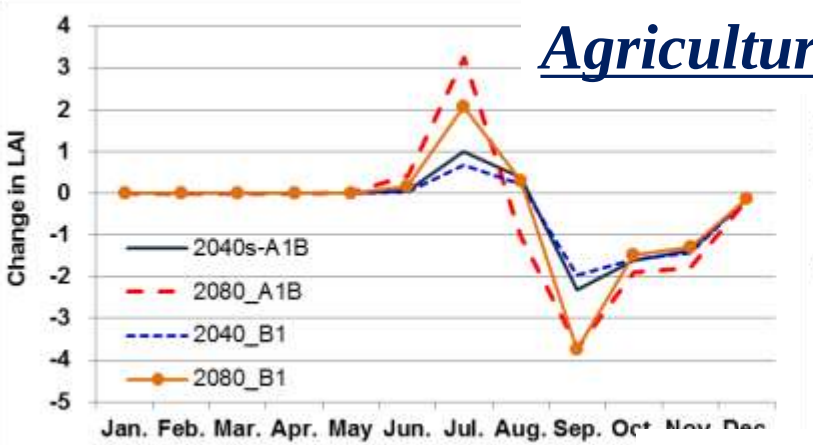


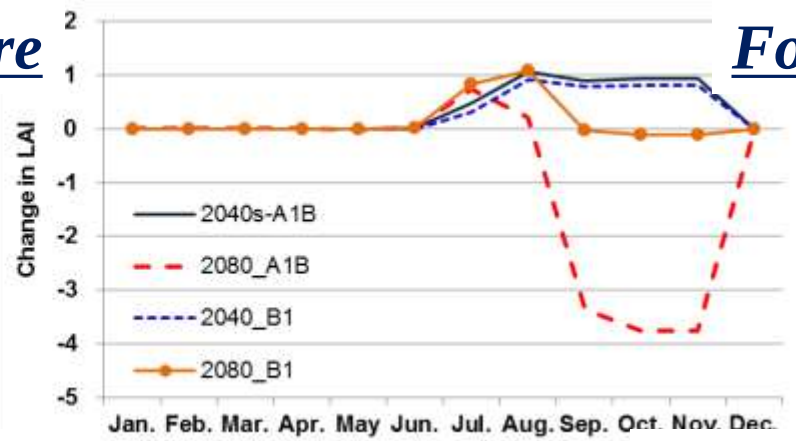
Watershed

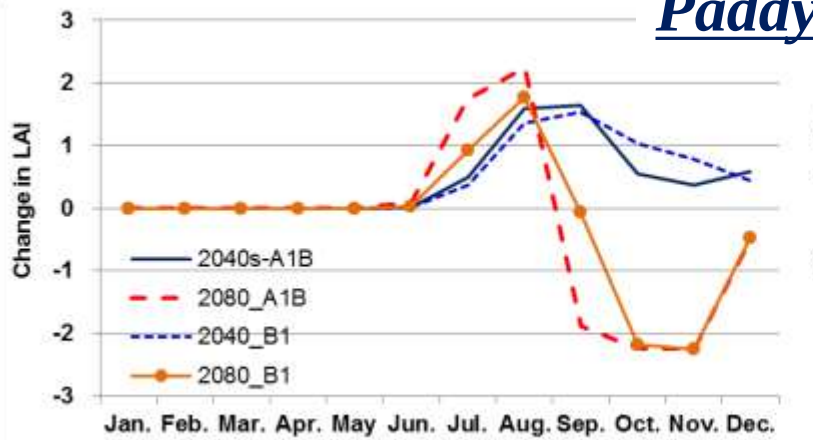


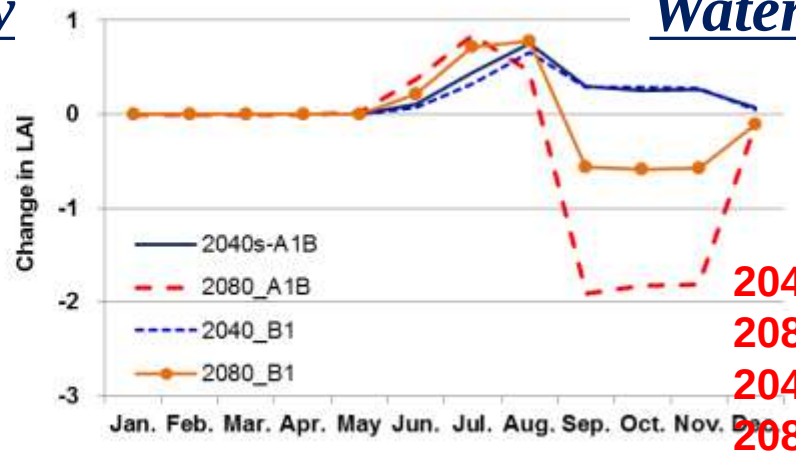
Results

- The change of monthly LAI in the 2040s and 2080s for A1B and B1 emission scenarios compared to the baseline (1990-2009)







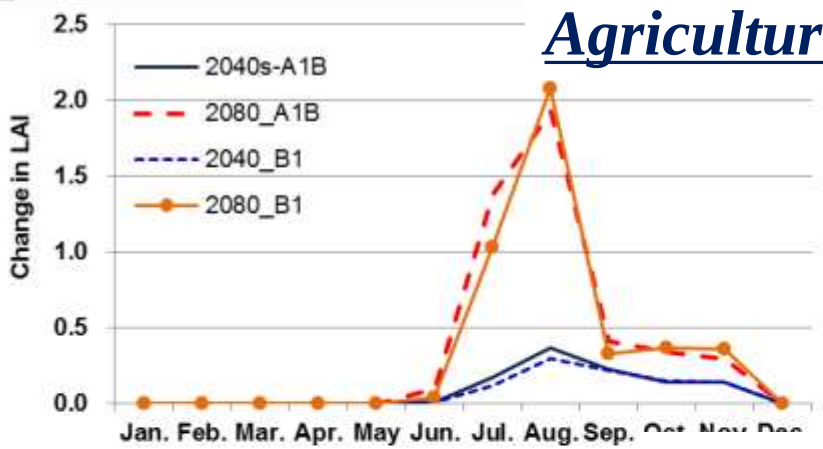


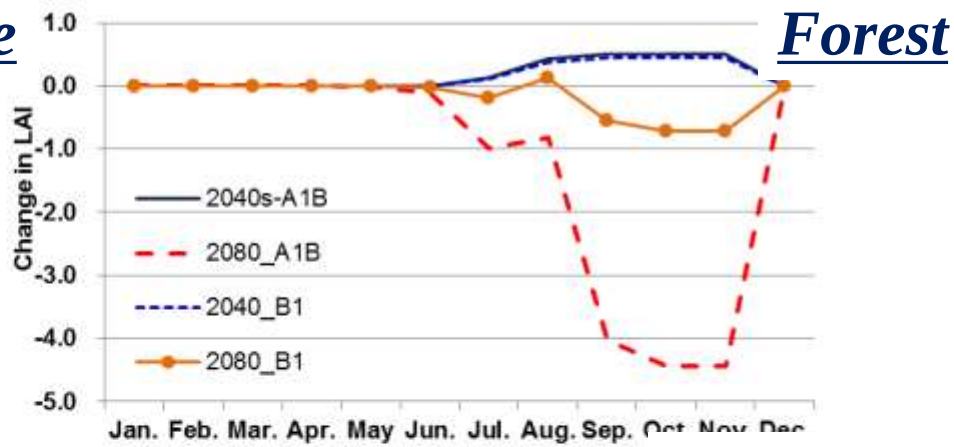
2040s-A1B: +0.18
2080s-A1B: -0.33
2040s-B1: +0.16
2080s-B1: -0.01

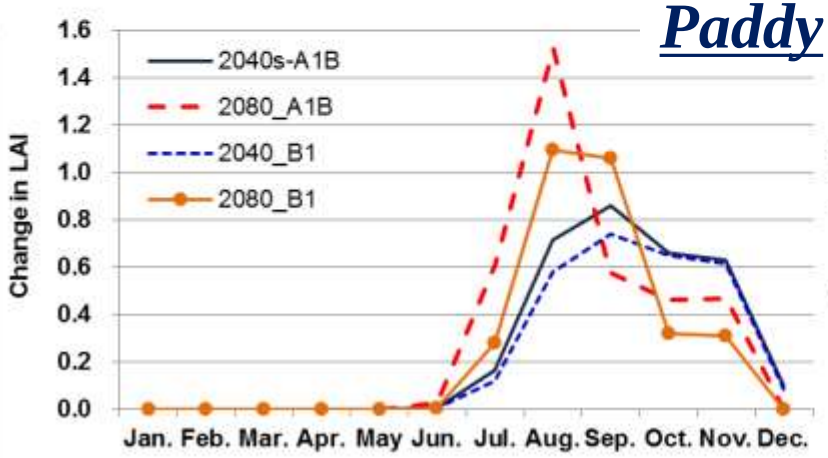
Results

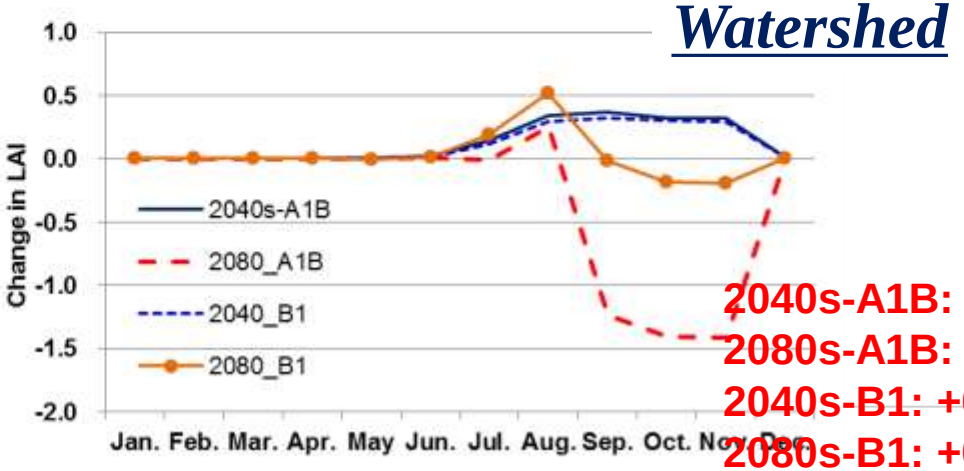
Average CO_2 concentration (ppmv)
Default: 330.0
2040s-A1B: 486.6
2080s-A1B: 636.0
2040s-B1: 456.8
2080s-B1: 525.8

- The change of monthly LAI considering future rising CO_2









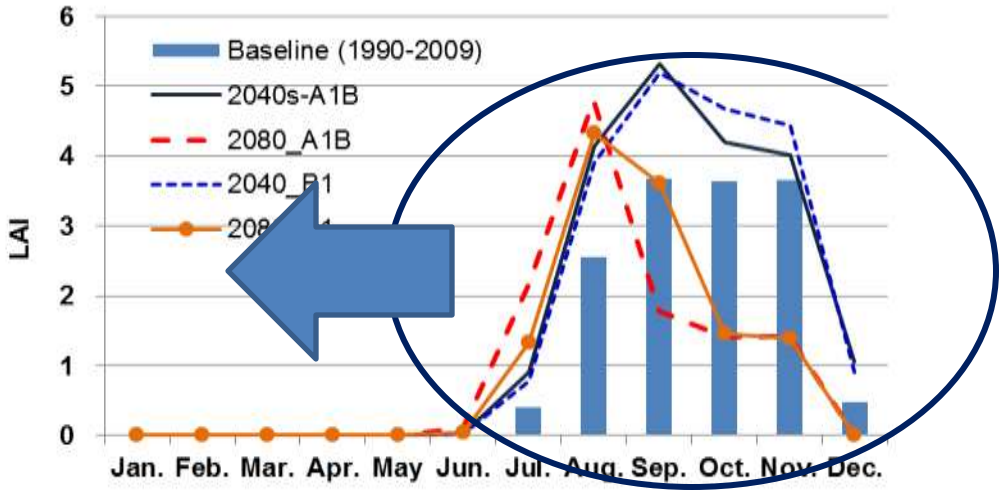
2040s-A1B: +0.13
2080s-A1B: -0.32
2040s-B1: +0.11
2080s-B1: +0.03

Summary & Conclusions

- **The SWAT was applied to assess the potential climate change impact on vegetation canopy and growth periods in forest watershed.**
  - **The CO_2 in 2080s A1B and B1 are 636.0 and 525.8 ppmv respectively.**
  - **The 2080s A1B and B1 downscaled data showed + 3.4 ℃ and + 2.4 ℃ temperature increase.**
  - **For the future A1B and B1 scenarios, the maximum changes in LAI were - 0.33 in 2080s and + 0.11 in 2040s respectively as a result of rising temperature and CO_2.**
  - **The nitrogen and phosphorus stresses cause RISING CO_2 which affects LAI and actual growth. We can find that each land use has an optimum CO_2 concentration.**

Summary & Conclusions

Paddy



- The simulated plant growth periods are distinguished from the present growth periods.

- We tried to identify the uncertainty of LAI by comparing the observed vs. simulated in order to reduce the unpredictable effects on it by climate change.

Thank you

iamg@konkuk.ac.kr

shjin@konkuk.ac.kr

bersayu@korea.kr

nemoik@konkuk.ac.kr

dolpin2000@konkuk.ac.kr

kimsj@konkuk.ac.kr