Hydro Predict 2012

The Impact of Climate Change on Water Supply

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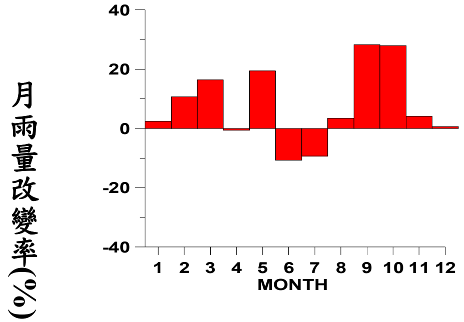
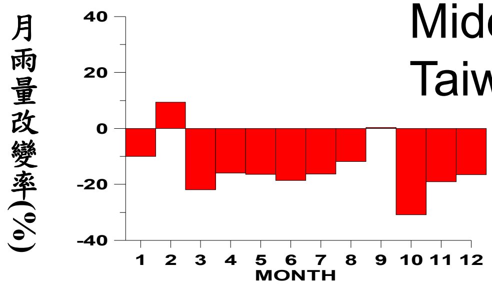
Content

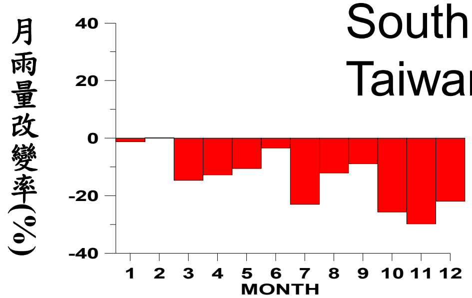
Introduction



Northern Taiwan

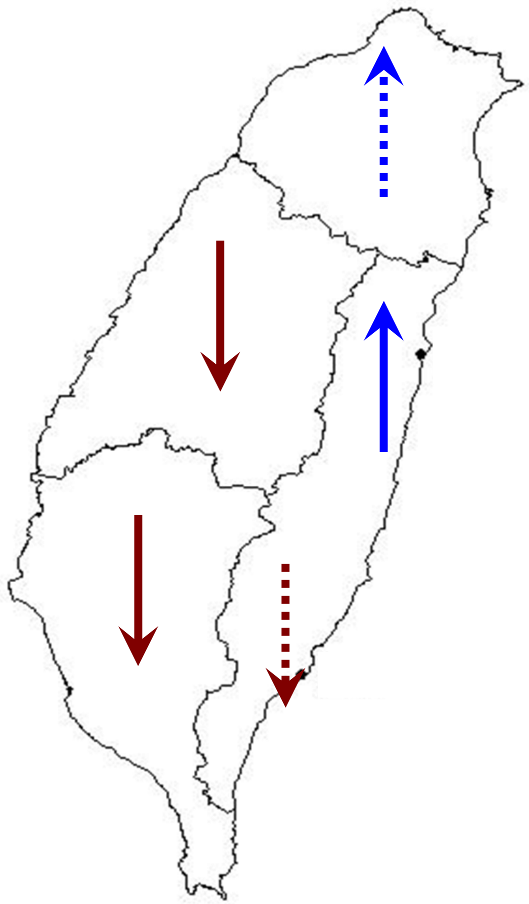


Middle Taiwan



Southern Taiwan

Precipitation Trend Tendency



A: 22(8) raingauge stations in Taiwan with over than 100(1906~) years historical data used for analysis.

B: Statistical method are used:

- **Cumulative Deviations**
- **Mann-Whitney-Pettitt**
- **Kruskal-Wallis**

C: The change point is aroud in1960

Introduction

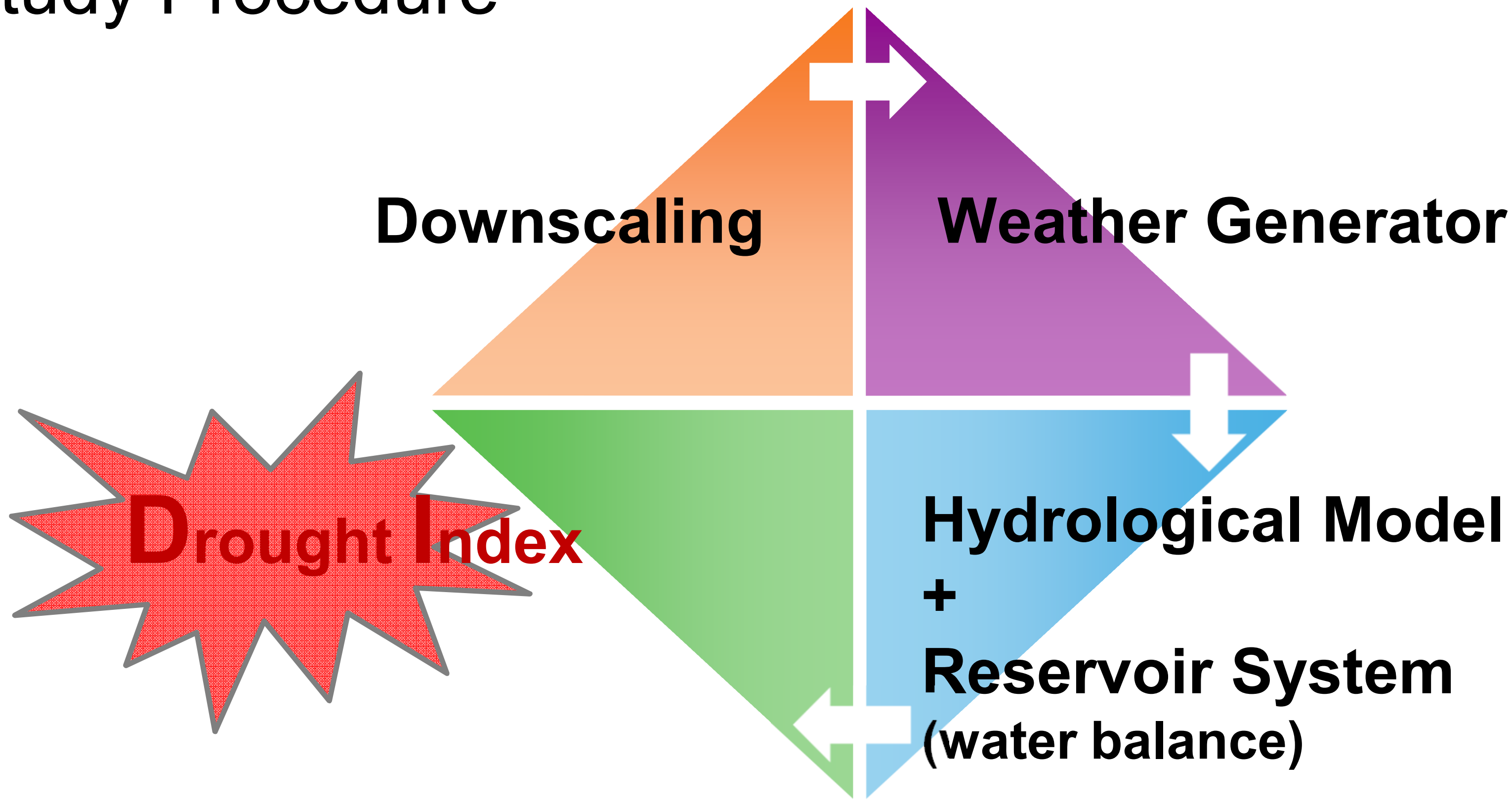
- The purpose of this study
  - assess the impact of climate change on water supply(drought risk) over Southern Taiwan
  - Which drought index is better to judge the risk of water supply
- The difference of drought index between the control(baseline) period (1980~1999) and the future period (2020~2049) under A1B emission scenario is only shown here.

Study Area and Dataset

- **Tseng-Wen Reservoir Catchment**
  - completed in 1973 with a storage capacity of about 780×10^6 m^3
  - The annual total water supply amount is 1,047 million tons.
  - The catchment of Tsengwen Reservoir encloses an area of 481 km^2
  - Observed data from 1975 to 2010 were collected

Methodology

Study Procedure

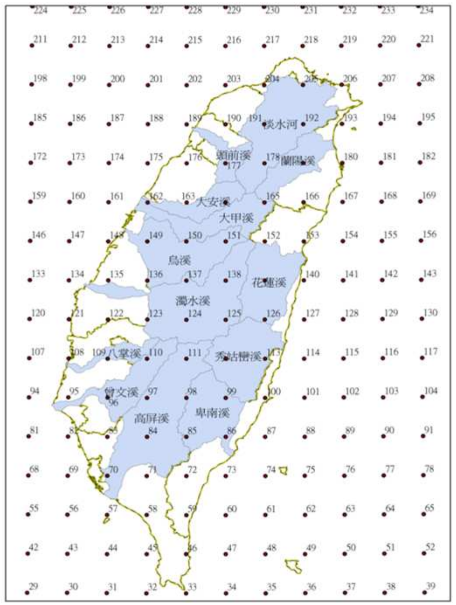


is used to address the impact of climate change on water supply

Methodology

Downscaling Results

directly collect from the project of Taiwan Climate Change Projection and Information Platform



Resolution: 25km×25km

Source: NCDR

General information of selected GCMs

GCM Acronym	Country
CGCM3.1(T63)	Canada
CSIRO-Mk3.5	Australia
ECHAM5/MPI-OM	Germany
GFDL-CM2.0	United States
GFDL-CM2.1	United States
MRI-CGCM2.3.2	Japan
MIROC3.2(hires)	Japan

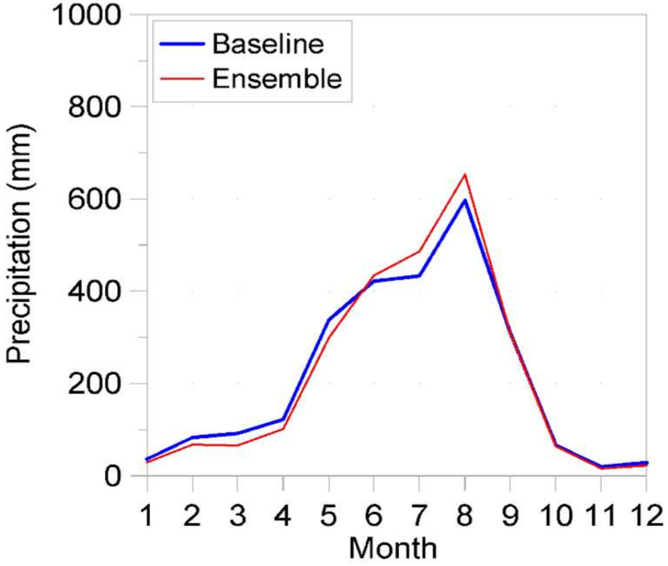
Source: http://www.ipcc-data.org/index.html

The GCMs which can reasonably simulate **tropical cyclone index** and **large scale circulation pattern** were used in this study.

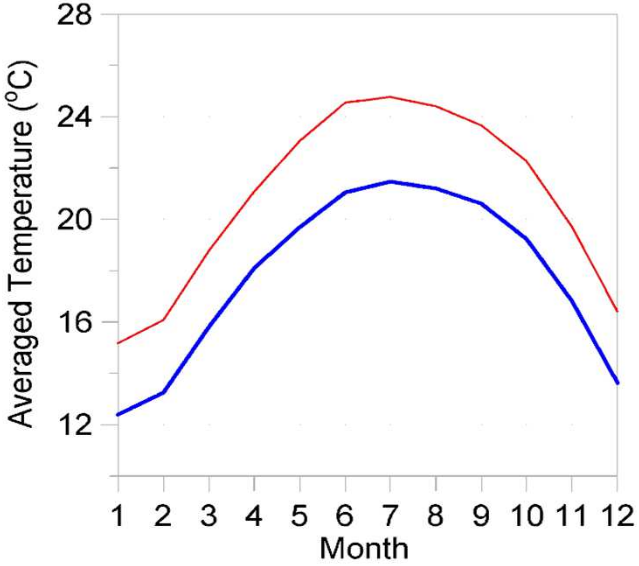
Downscaling Results

- **Impact of Climate Change on Hydrology**

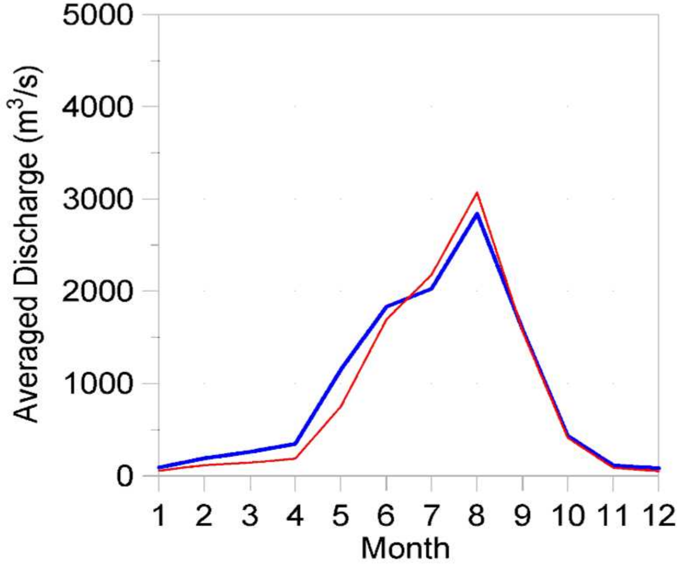
Rainfall



Temperature



Runoff



- **Results Under A1B- Scenario** [S: stand for the time period from 2020 to 2039]

Runoff will be increased during the period from July to Sep

The runoff of remaining months will be decreased

Methodology

- **Weather Generator**

Synthesize daily rainfall and temperature data

- **Daily Rainfall Data is generated**

First-order Markov Chain [transition probability]

Probability distribution [Weibull distribution]

- **Temperature Data**

First-order regression model

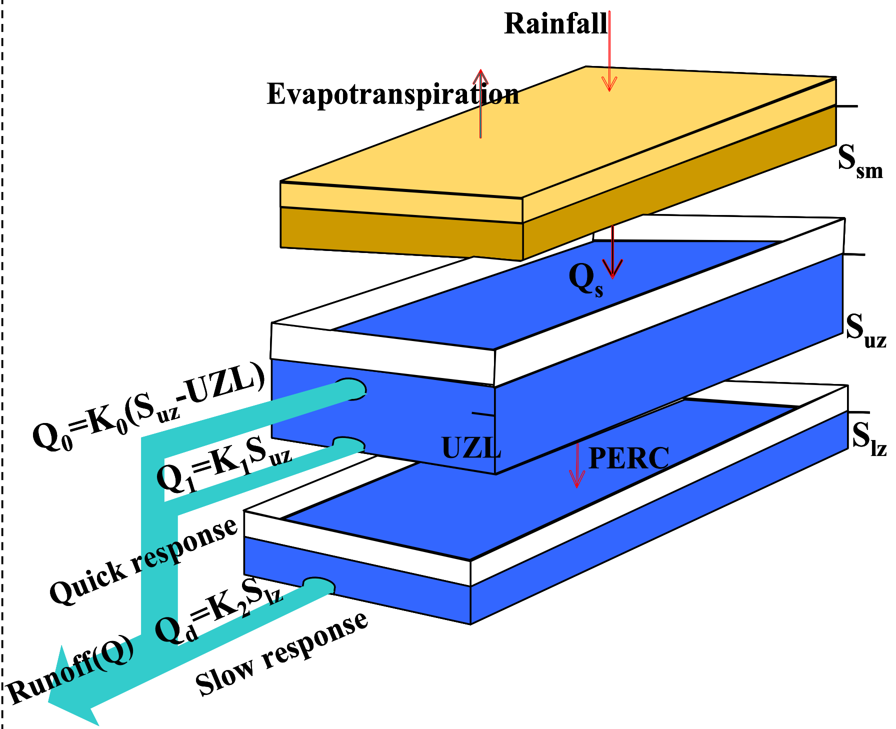
$$T_k = \mu_t + \rho_{1t}\left(t_{k-1} - \mu_t\right) + \sqrt{1 - \rho_{1t}^2}\,\sigma_t v_k$$

Methodology

Hydrological Model

Use to simulate the inflow of Tseng-Wen Reservoir catchment

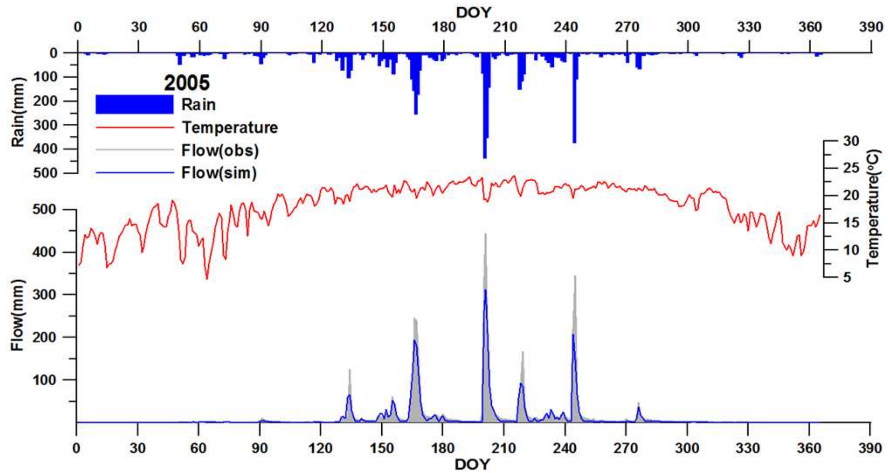
Model Structure



➔ An HBV-based Model

The model consists of following three parts:

- **Soil Moisture Module**
- **Runoff Response**
- **Water Balance Functions**



Hydrological Calibration and verification

- Calibration period：1975~1999年
- Verification period：2000~2008年
  - Criteria

Criteria	Mean Error (mm)	Coefficient of correlation	Root mean square error (mm)
Calibartion	0.957	0.938	6.849
Verification	0.985	0.964	9.539

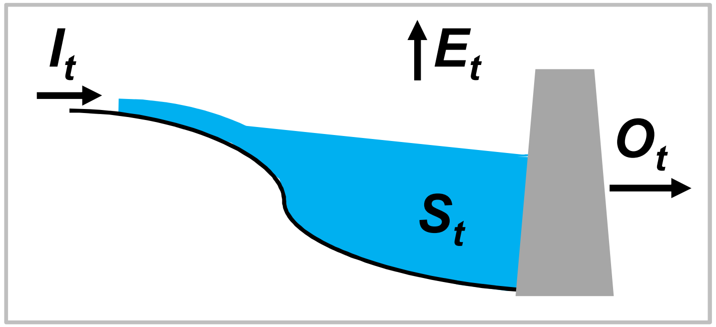
  - 參數率定值

FC	beta	LP/FC	PERC	UZL	K0	K1	K2	C_e
245.937	1.264	0.05	5.423	32.743	0.659	0.008	0.161	0.715

Methodology

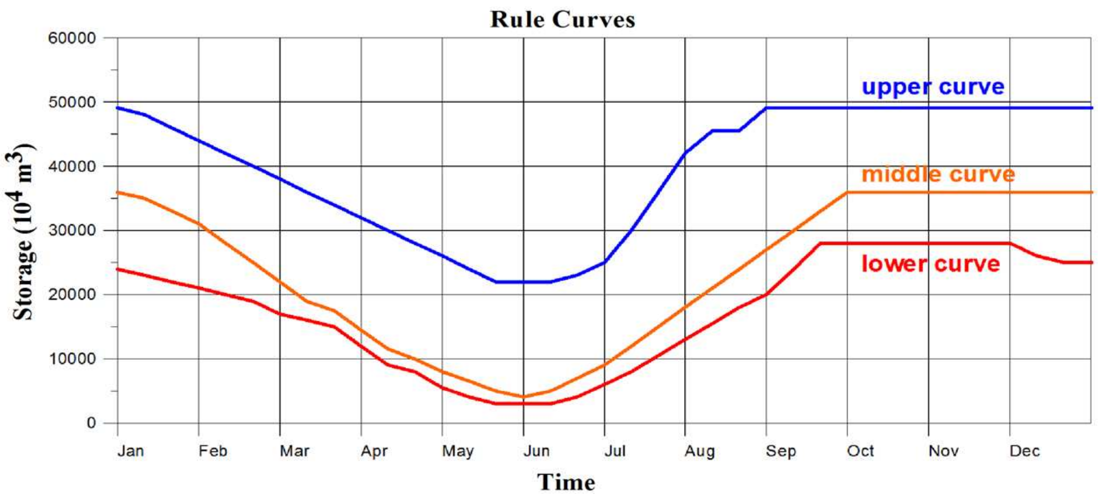
Reservoir System

"Continuity Equation" is used to model the water supply process



$$S_{t+1} = S_t + I_t - O_t - E_t$$

Operating Rule [Agricultural Water Supply]



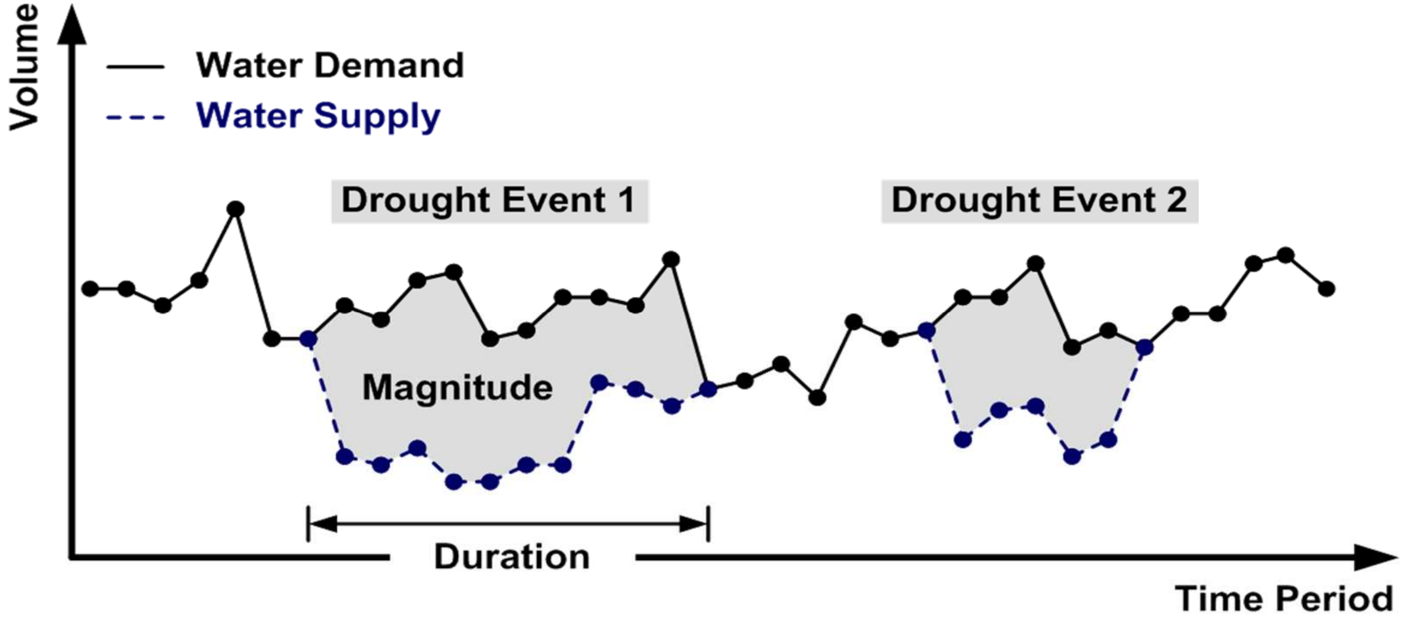
Supply 100%

Supply will be reduced 25%

Supply will be reduced 50%

Methodology

- **Drought Index**
  - **Drought (water shortage) Definition:** Drought occurs when supply can’t meet demand

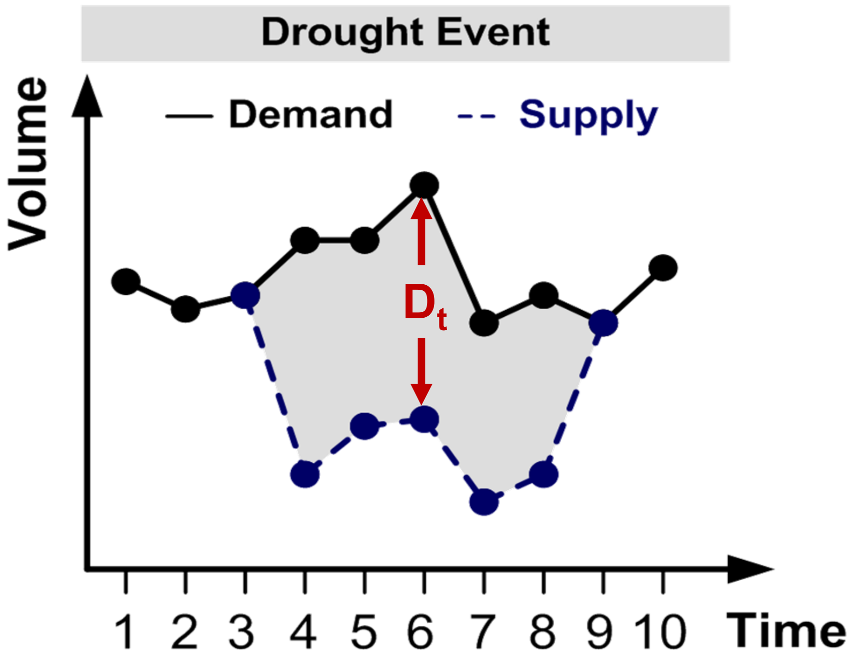


- **Drought Index**

Various indices are proposed to characterize drought events

Methodology

- Drought Index
  - Single Index



Reliability

Related to the duration of drought events

$$Rel = 1 - \frac{No.of\ days\ D_t > 0}{n}$$

Vulnerability

Related to the magnitude of drought events

$$Vul = \frac{\sum_{t=1}^{t=n} D_t \Big/ No.\ of\ \ days\ D_t > 0}{Total\ \ Water\ \ Demand}$$

Resilience

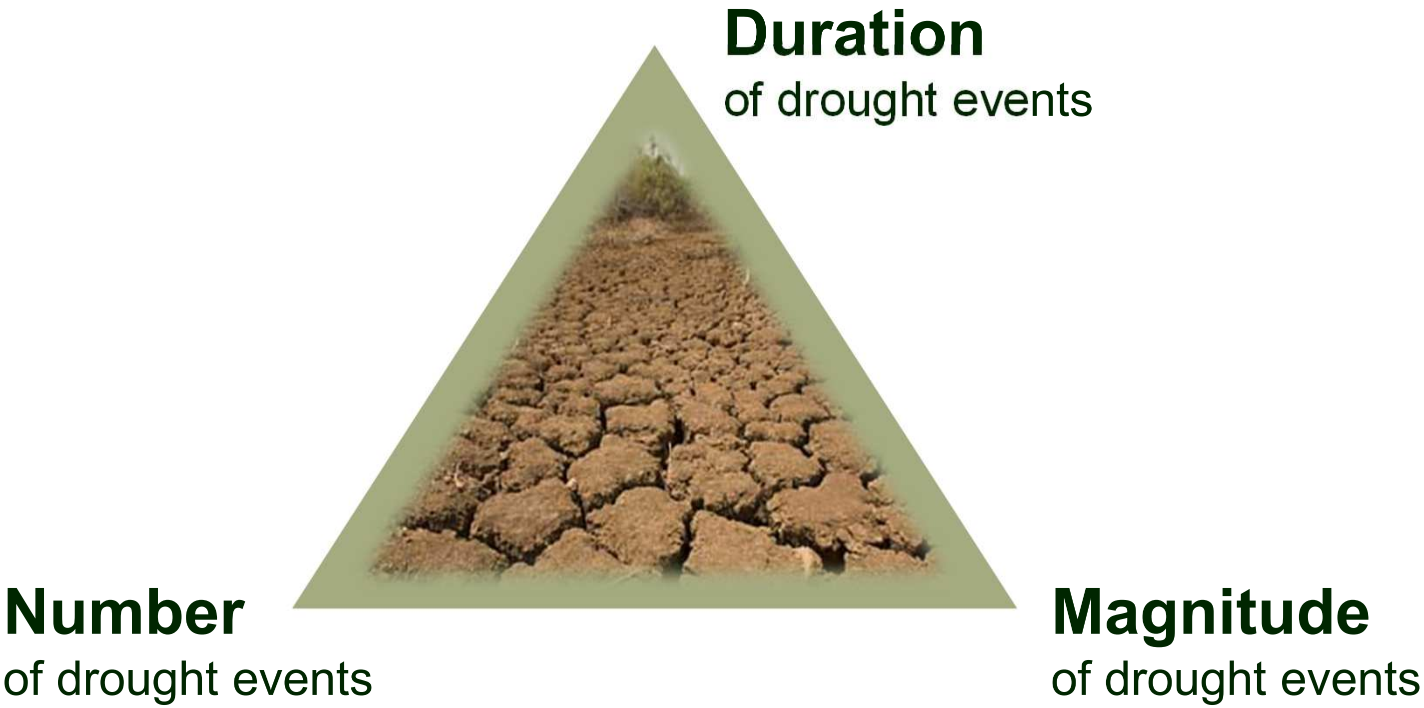
Related to the number of drought events

$$Res = \frac{No.\ of\ \ days\ D_t = 0\ follows\ D_t > 0}{No.\ of\ \ days\ D_t > 0}$$

Methodology

- **Drought Index**
  - **Multiple Index**

It can can measure various characteristics of drought event at the same time (give more information)



Methodology

Multiple Index

Sustainability Index

$$SUI = [Rel \times Res \times (1 - Vul)]^{1/3}$$

Positive index [the greater the better]
Geometric mean
Value varies from 0 to 1

Drought Risk Index

$$DRI = w_1(1 - Rel) + w_2(1 - Res) + w_3(1 - Vul)$$

$$w_1 + w_2 + w_3 = 1$$

Negative index [the less the better]
Arithmetic mean
Value varies from 0 to 1

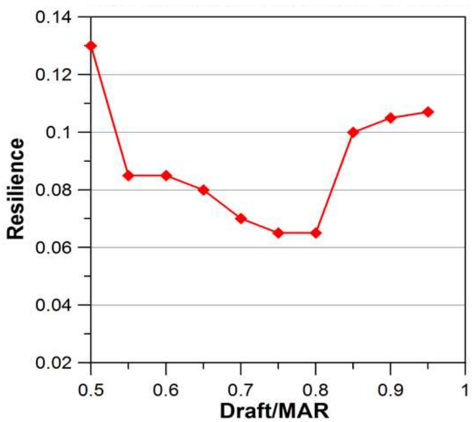
Results of Drought Index Performance

Criterion to choose a good index

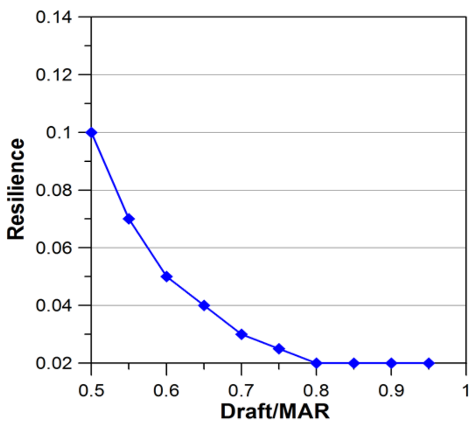
A good drought index should be monotonic

Jain SK (2010) Investigating the behavior of statistical indices for performance assessment of a reservoir. *Journal of Hydrology*, 391, pp90-96.

Non-monotonic Behavior



Monotonic Behavior



Examination Process

Drought Index → **Variable** → **Behavior**

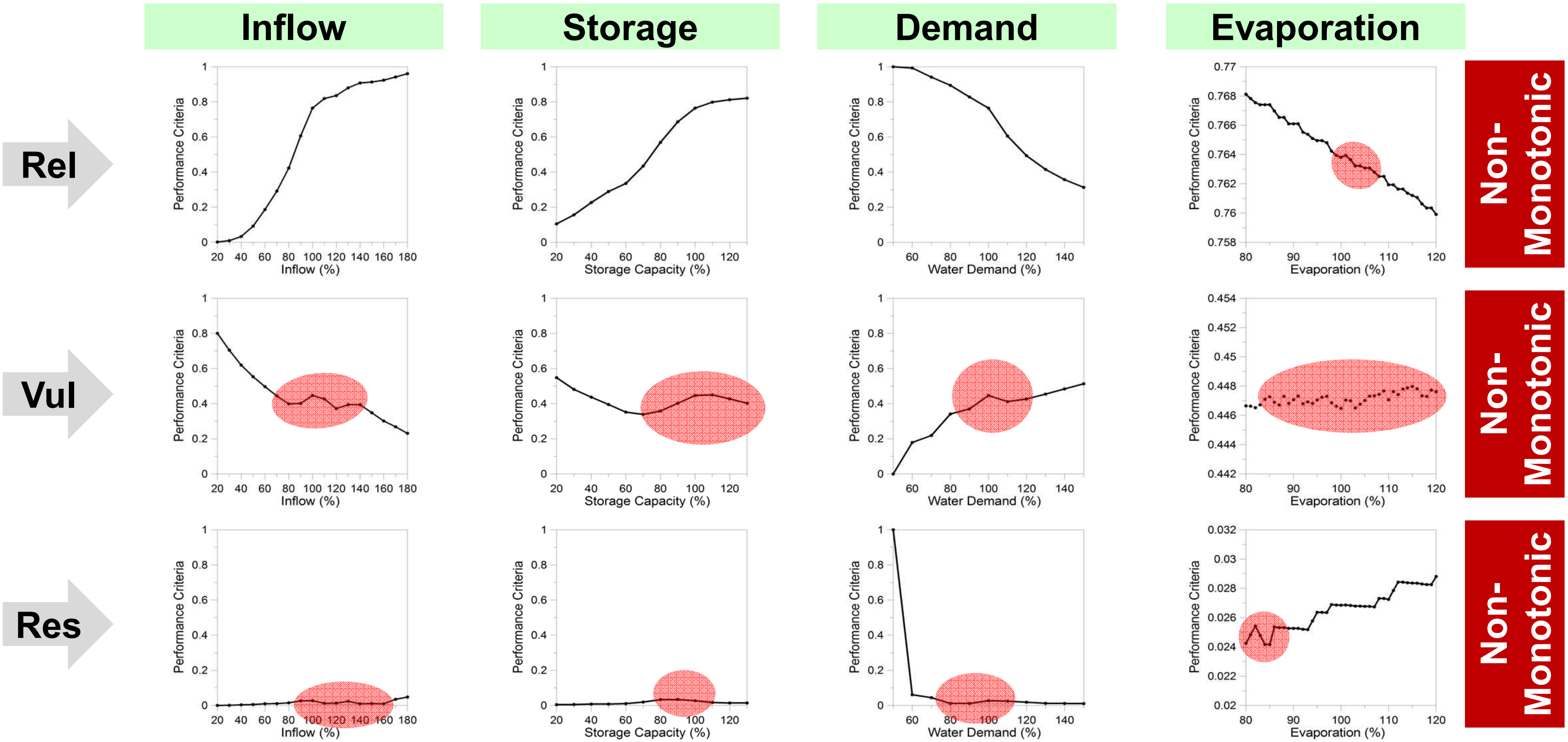
Selected indices:
Rel, Vul, Res, SUI, DRI & MDRI

Independent Variables:
Storage, Inflow, Demand & Evaporation

Examination Results:
Monotonic or Non-monotonic

Results of Drought Index Performance

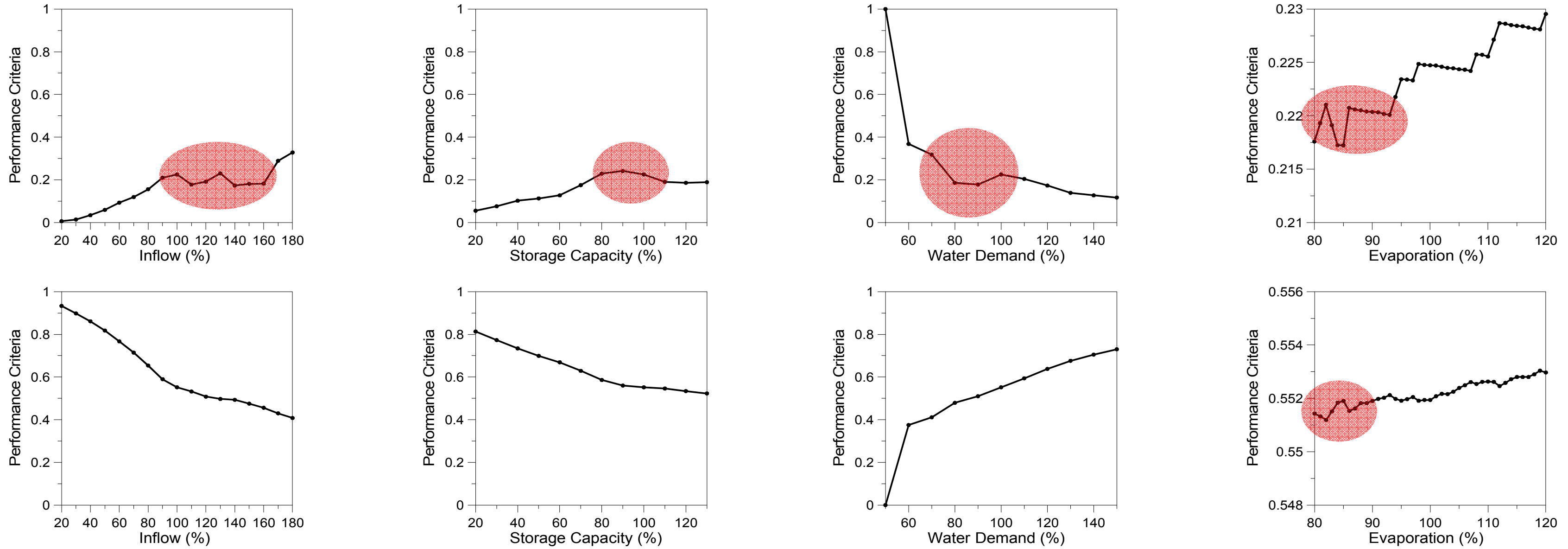
- **Performance of Monotonic**



Results of Drought Index Performance

- **Performance of Monotonic**

	Inflow	Storage	Demand	Evaporation	
SUI					Non-Monotonic
DRI					Non-Monotonic



Modification of Drought Index

- **Multiple Index**

Sustainability Index

Positive index [the greater the better]
Geometric mean
Value varies from 0 to 1

Drought Risk Index

Negative index [the less the better]
Arithmetic mean
Value varies from 0 to 1

Modified Drought Risk Index

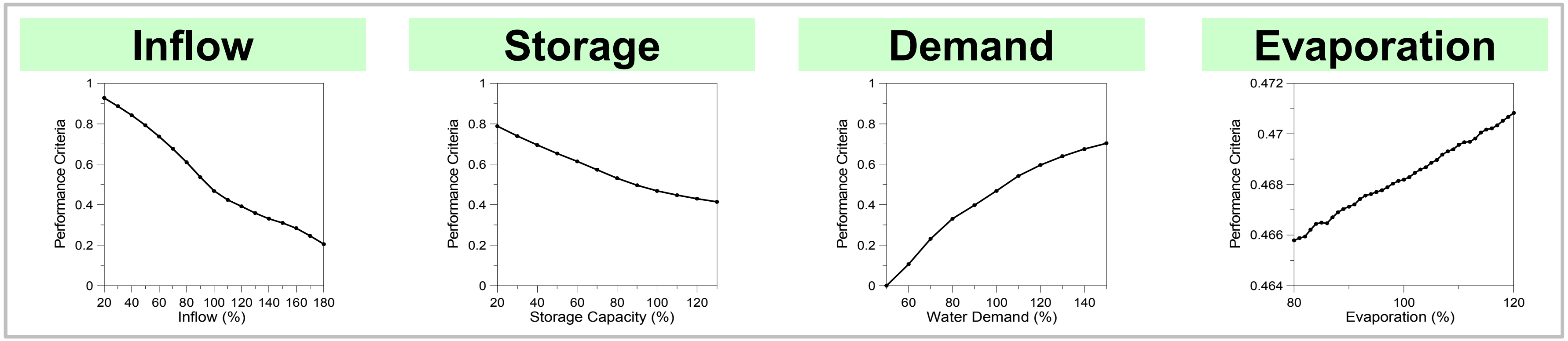
Geometric mean
Negative index [the less the better]
Value varies from 0 to 1

$$MDRI = [(1 - Rel) \times (1 - Res) \times Vul]^{1/3}$$

Results & Discussion

Performance of Monotonic

MDRI



Monotonic

■ Results

MDRI is a multiple index which can provide more information about drought events and is also a monotonic index

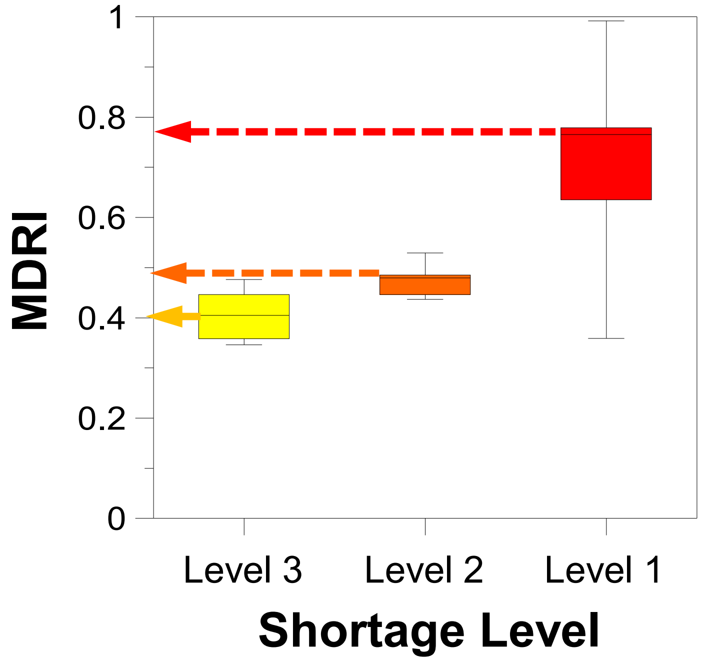
➔ This Study uses MDRI for further discussion

An efficient and suitable index for drought events

Results of Impact of Climate Change

Link MDRI to Existing Shortage Levels

Take public water supply as an example

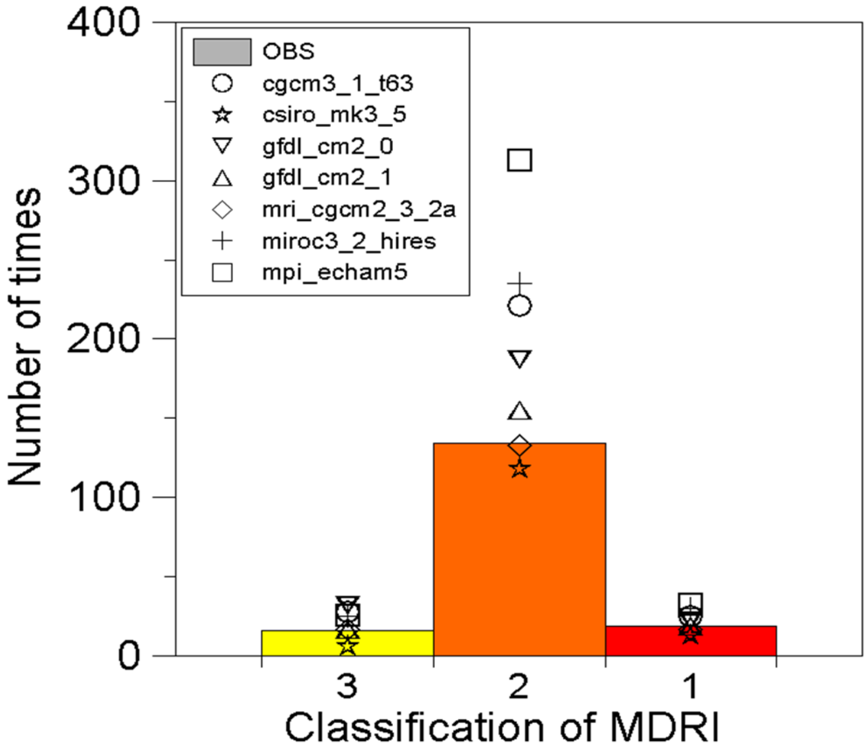


Classification of Water Shortage Level

Level	Deficit Rate	MDRI
Level 3	10~20%	0.4~0.5
Level 2	20~30%	0.5~0.8
Level 1	More than 30%	0.8~1.0

Results of Impact of Climate Change

- **Use MDRI to Assess Drought(water shortage) Index in 2020~2049**



Under A1B-S scenario

The number of level 2 drought events will increase 1.34 times

Conclusions

- **Impact of Climate Change on Hydrology**

Under A1B-S(2020~2049) scenario, runoff will increase during the period from Jul to Sep. However, runoff decreases during the remaining months

- **Multiple Drought Index**

This study would like to propose a multiple index (i.e., M_DRI) to address the drought characteristics. The analysis results show M_DRI is an efficient and suitable index for assessing the risk of water supply.

- **Risk of Water Supply Under Climate Change**

For public water supply, the number of level 2 drought event will increase 1.34 times under A1B-S scenario.

Thank You for Your Attention