Discussion of a Decade Accumulative Assessment from Baseline for Future Climate Change Impact on Watershed Hydrology and Water Quality using SWAT

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Contents

Introduction

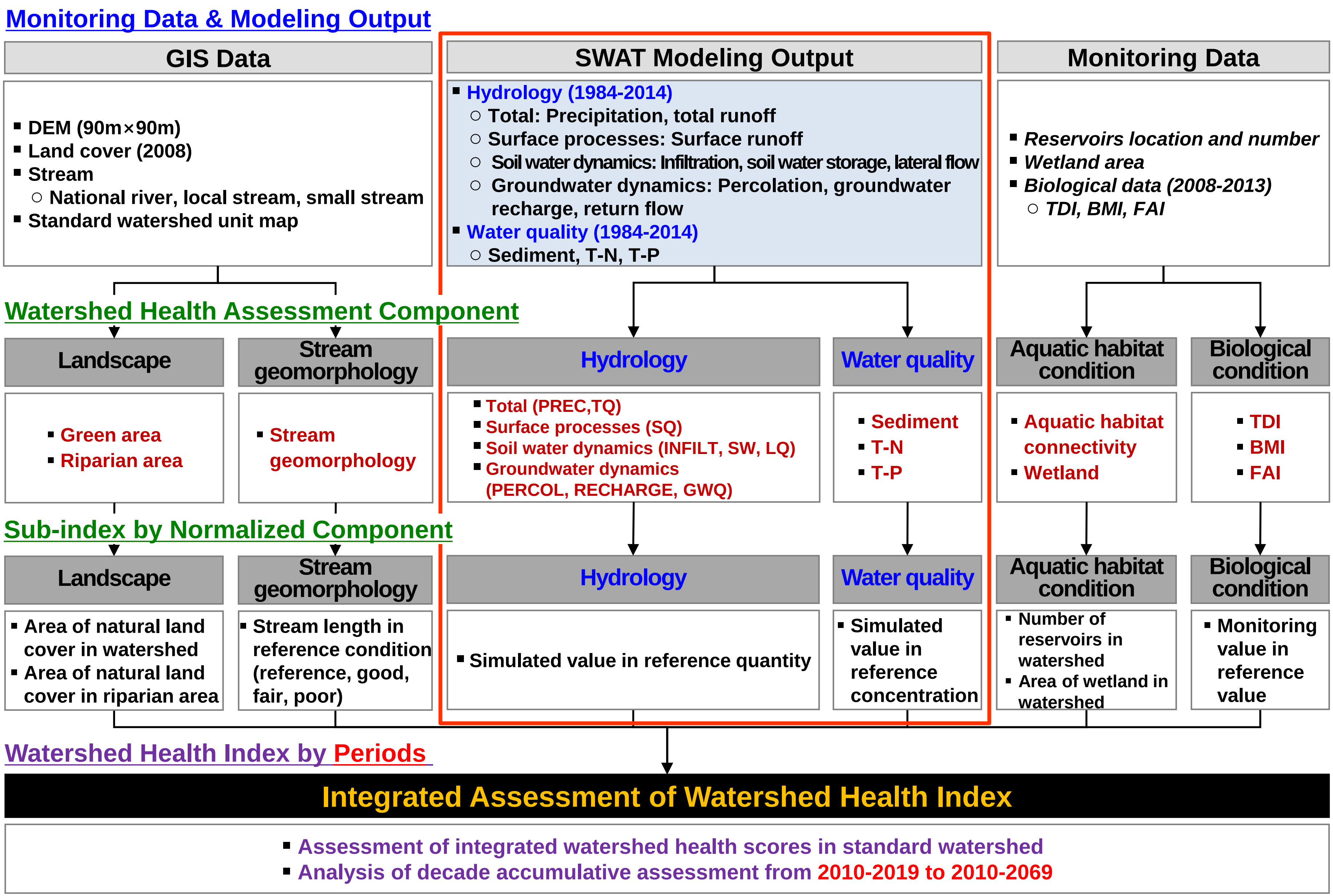
- **Watershed management** can be defined as the integrated and iterative decision process applied to maintain the sustainability of resources through the balanced use and conservation of water quantity and water quality.

- The intergovernmental Panel on Climate Change (IPCC) has recognized that **future climate change** will exacerbate the current stress on water resources (IPCC, 2007). According to IPCC Assessment Report 5 (AR5), water resources can be adapted to climate change by developing adaptive integrated water resource management.

- For climate change adaptation, **it is necessary establish a clear roadmap for policy formulation in different periods** (eq., 5 years, 10 years, short, medium and long term). Practically, **the government requests the adaptation plan for watershed** management by climate change, for example, until 2020 or 2030 from present.

- The main objective of this study is **designed to investigate projected results of future time periods**, by **using a decadal accumulative** evaluation approach relative to the baseline time periods.

Flowchart


Monitoring Data & Modeling Output
GIS Data
▪ DEM (90m×90m)
▪ Land cover (2008)
▪ Stream
○ National river, local stream, small stream
▪ Standard watershed unit map
SWAT Modeling Output
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▪ Riparian area
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▪ Stream geomorphology
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▪ Surface processes (SQ)
▪ Soil water dynamics (INFILT, SW, LQ)
▪ Groundwater dynamics (PERCOL, RECHARGE, GWQ)
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▪ Sediment
▪ T-N
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▪ Aquatic habitat connectivity
▪ Wetland
Biological condition
▪ TDI
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▪ FAI
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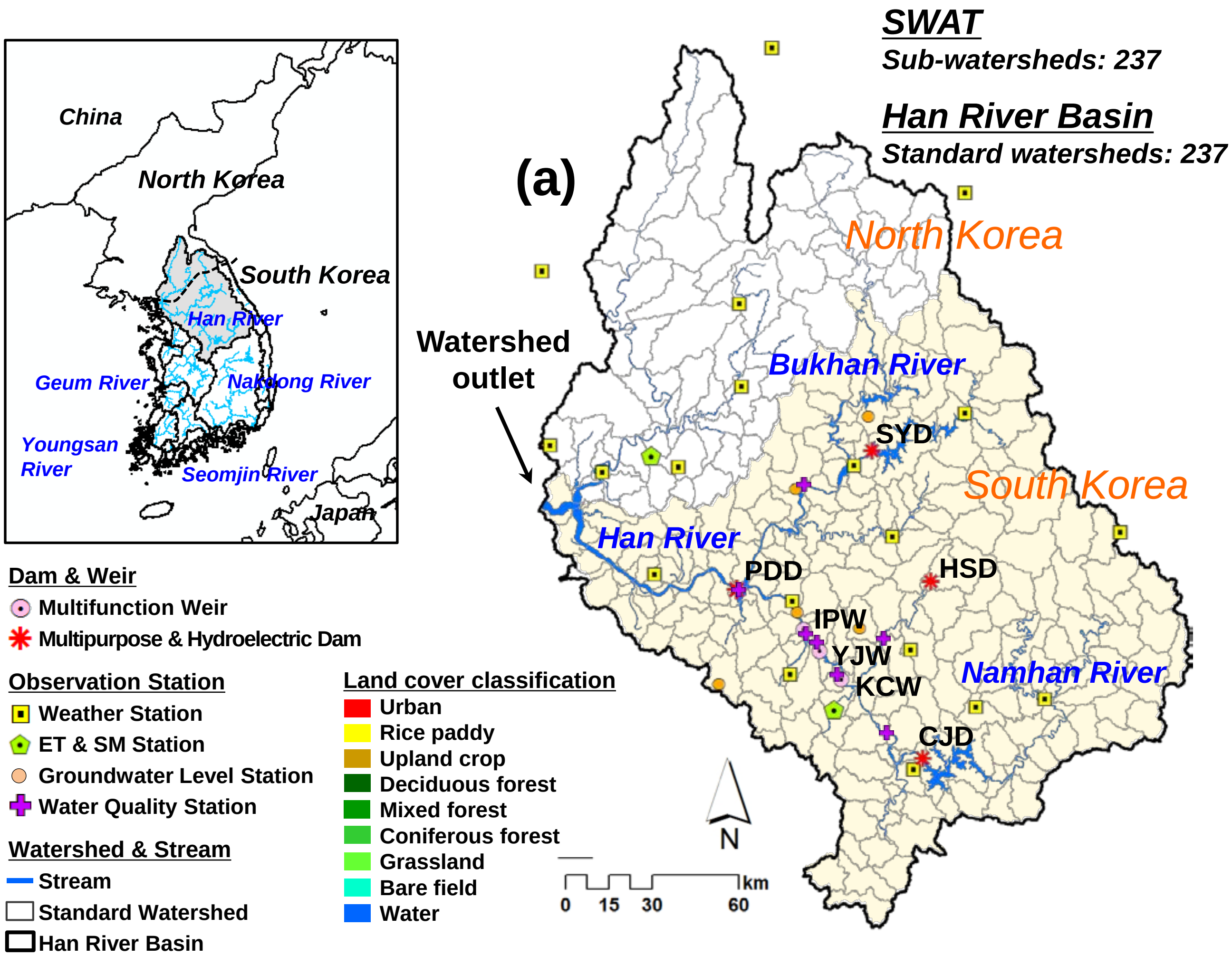
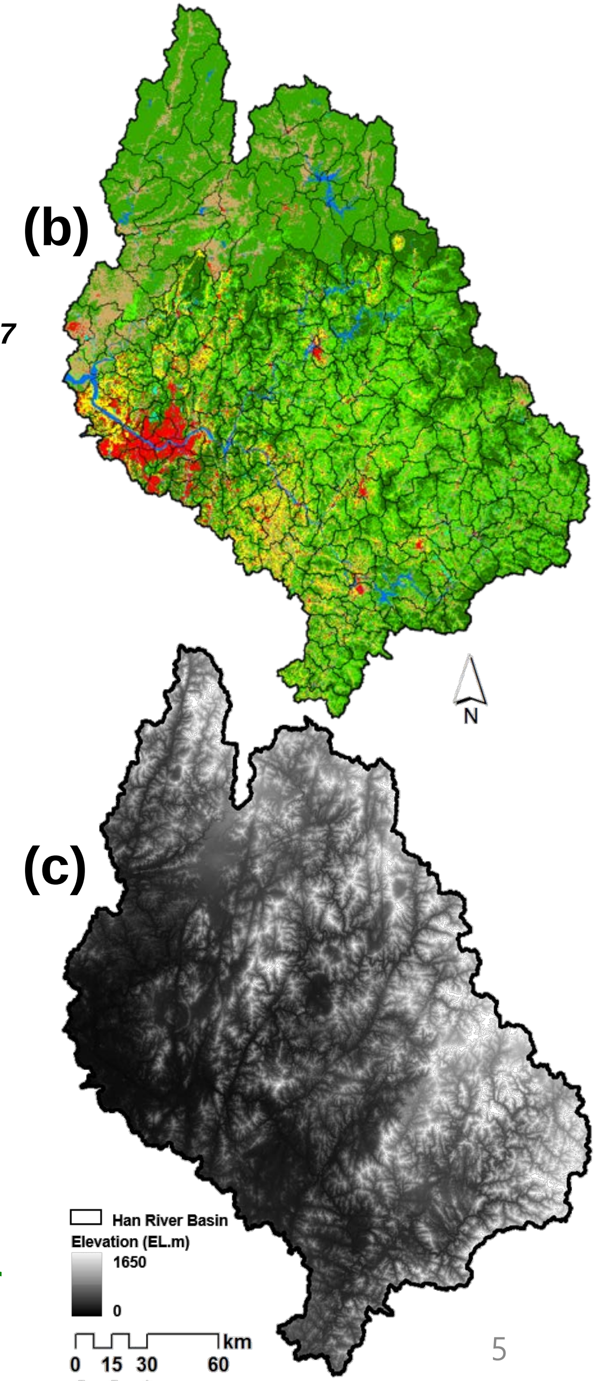
▪ Area of natural land cover in riparian area
Stream geomorphology
▪ Stream length in reference condition (reference, good, fair, poor)
Hydrology
▪ Simulated value in reference quantity
Water quality
▪ Simulated value in reference concentration
Aquatic habitat condition
▪ Number of reservoirs in watershed
▪ Area of wetland in watershed
Biological condition
▪ Monitoring value in reference value
Watershed Health Index by Periods
Integrated Assessment of Watershed Health Index
▪ Assessment of integrated watershed health scores in standard watershed
▪ Analysis of decade accumulative assessment from 2010-2019 to 2010-2069

Study Area





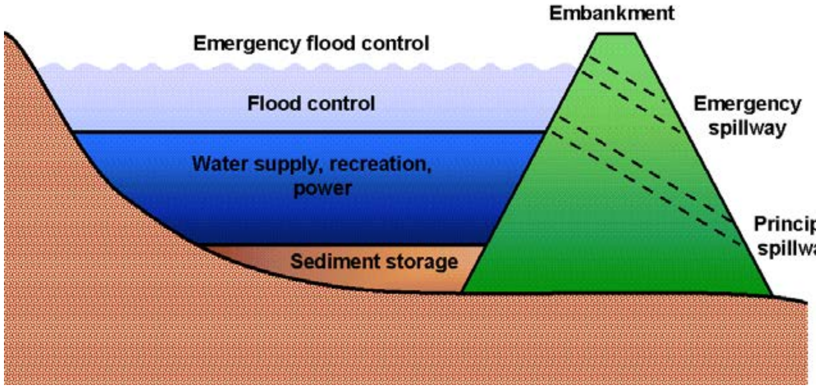
- Han River basin (34,148 km²)
  - ✓ Average annual precipitation 1,395 mm/year
  - ✓ Mean annual temperature 11.5℃

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).

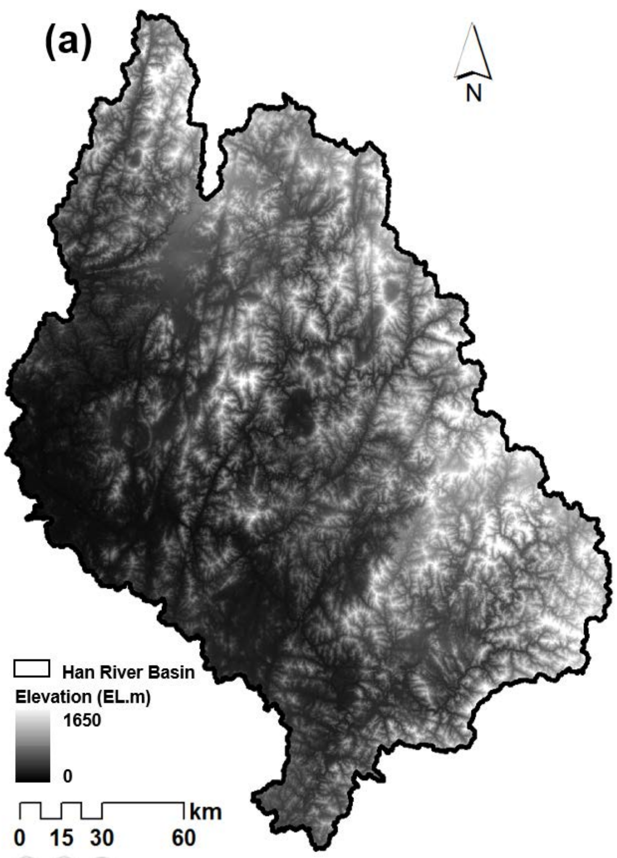
Data for SWAT model evaluation

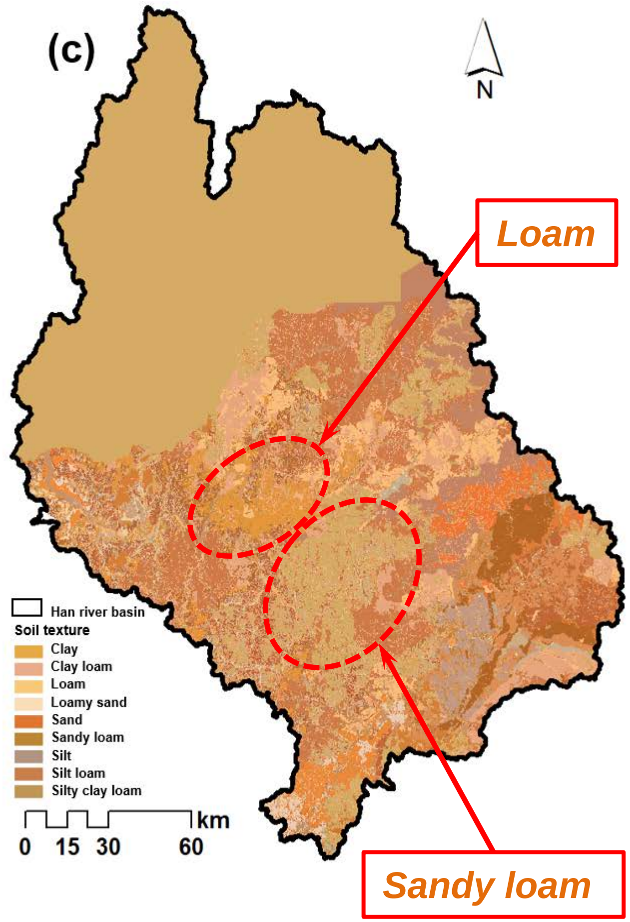
GIS data

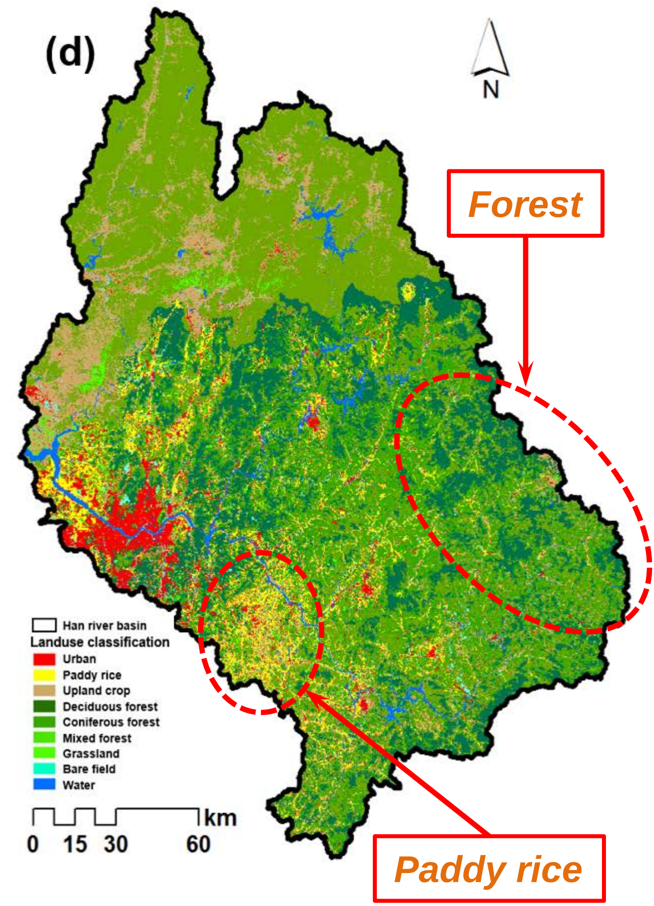
***Elevation** : 0 - 1650m (SRTM 90m grid size)*

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

***Land cover (2008)** : Forest (73%) and paddy rice (6%)*

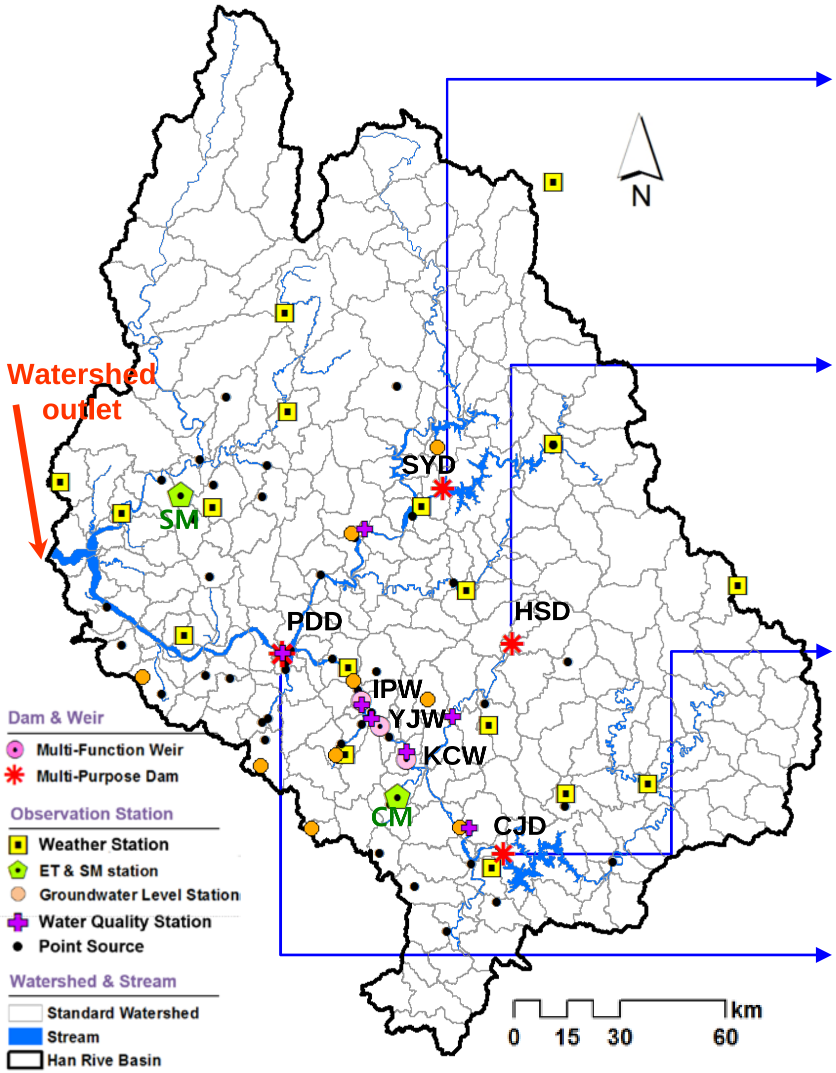


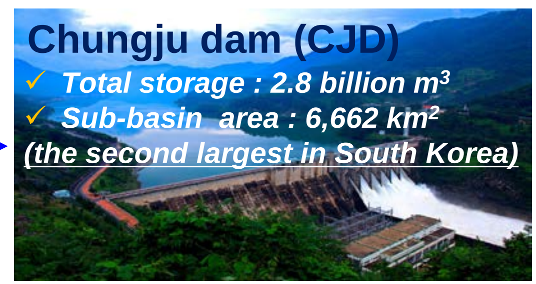


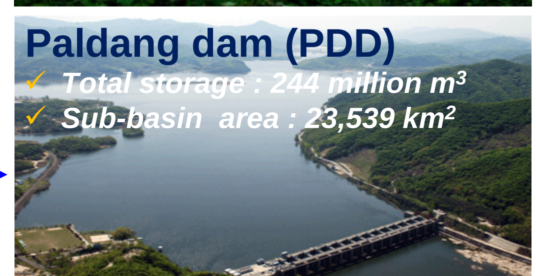


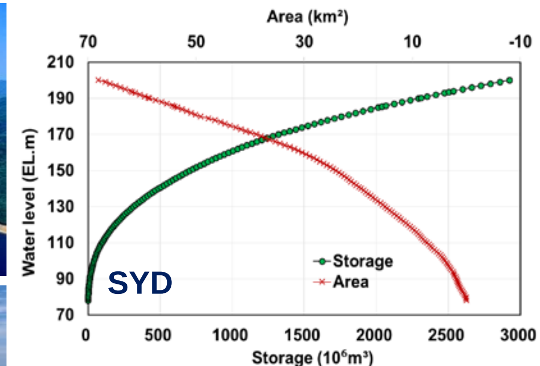
Data for SWAT model evaluation

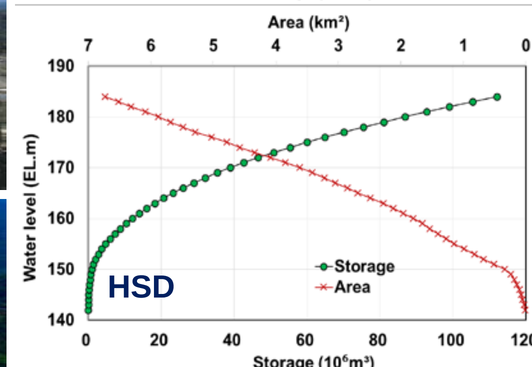
4 Multipurpose dam data (area-level and storage-level relationship curve)

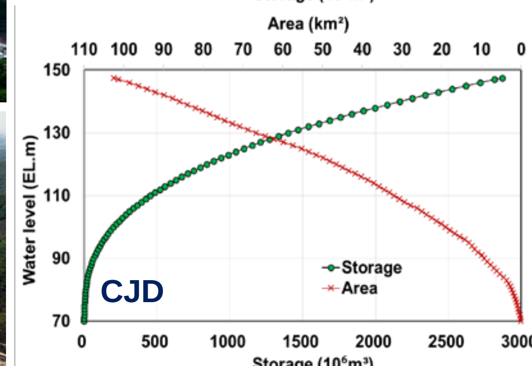






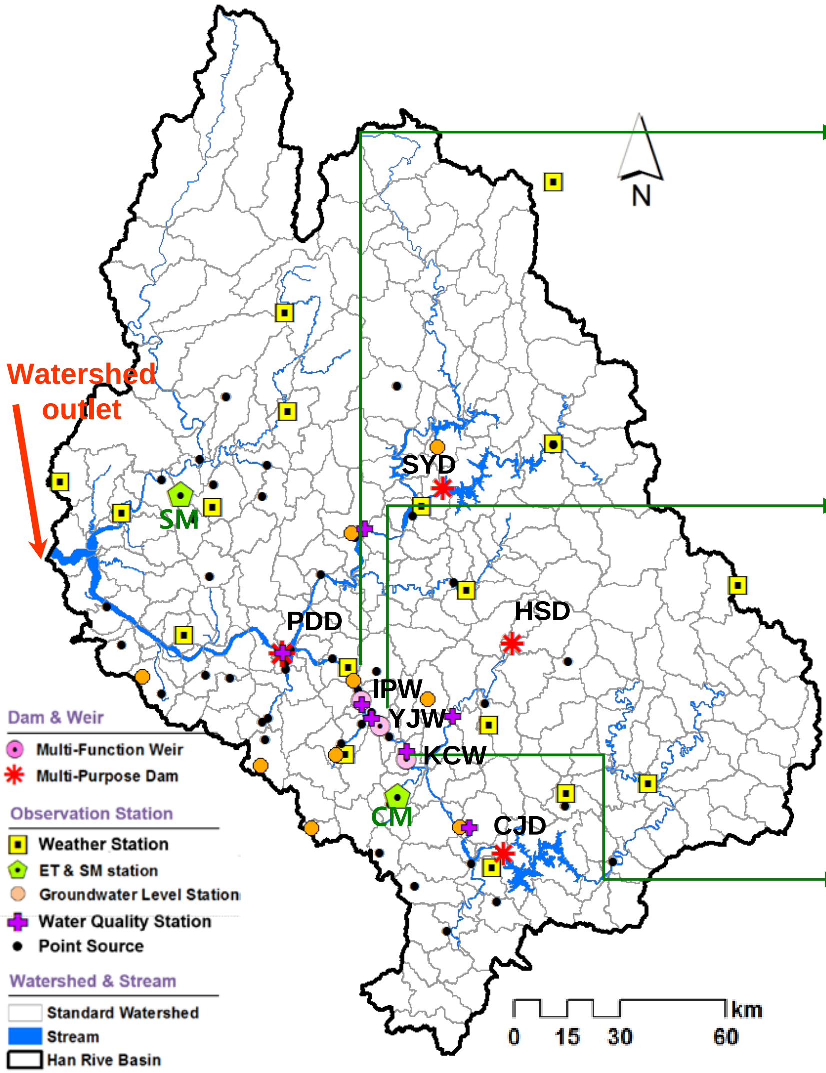


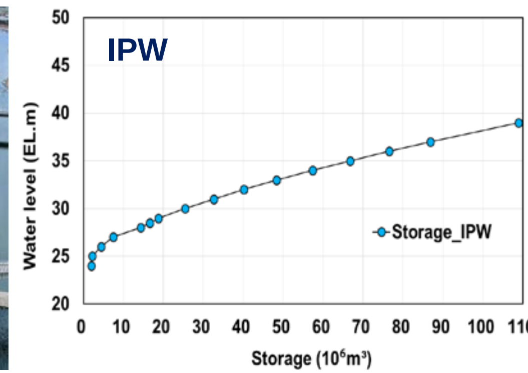


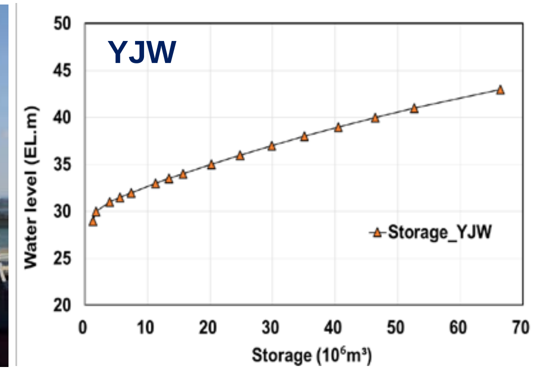


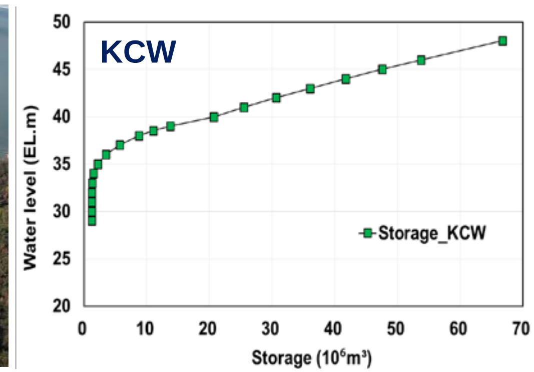
Data for SWAT model evaluation

3 <u>Multifunction weir</u> data (area-level and storage-level relationship curve)







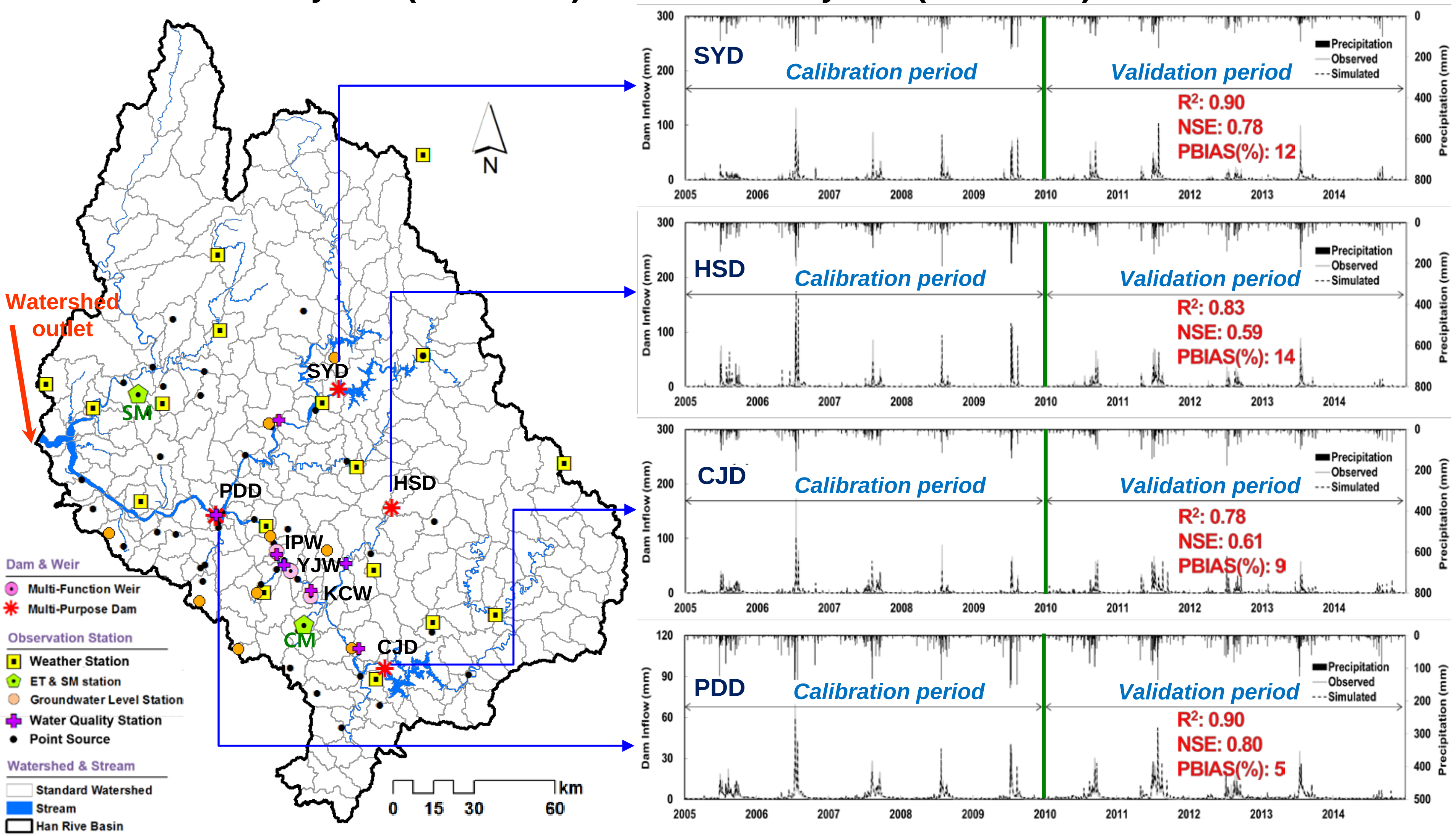


Model calibration and validation

Ahn et al., (2016)

Observed vs. simulated streamflow results of model calibration and validation

✓ **Calibration :** 5 years (2005-2009) / **Validation :** 5 years (2010-2014)

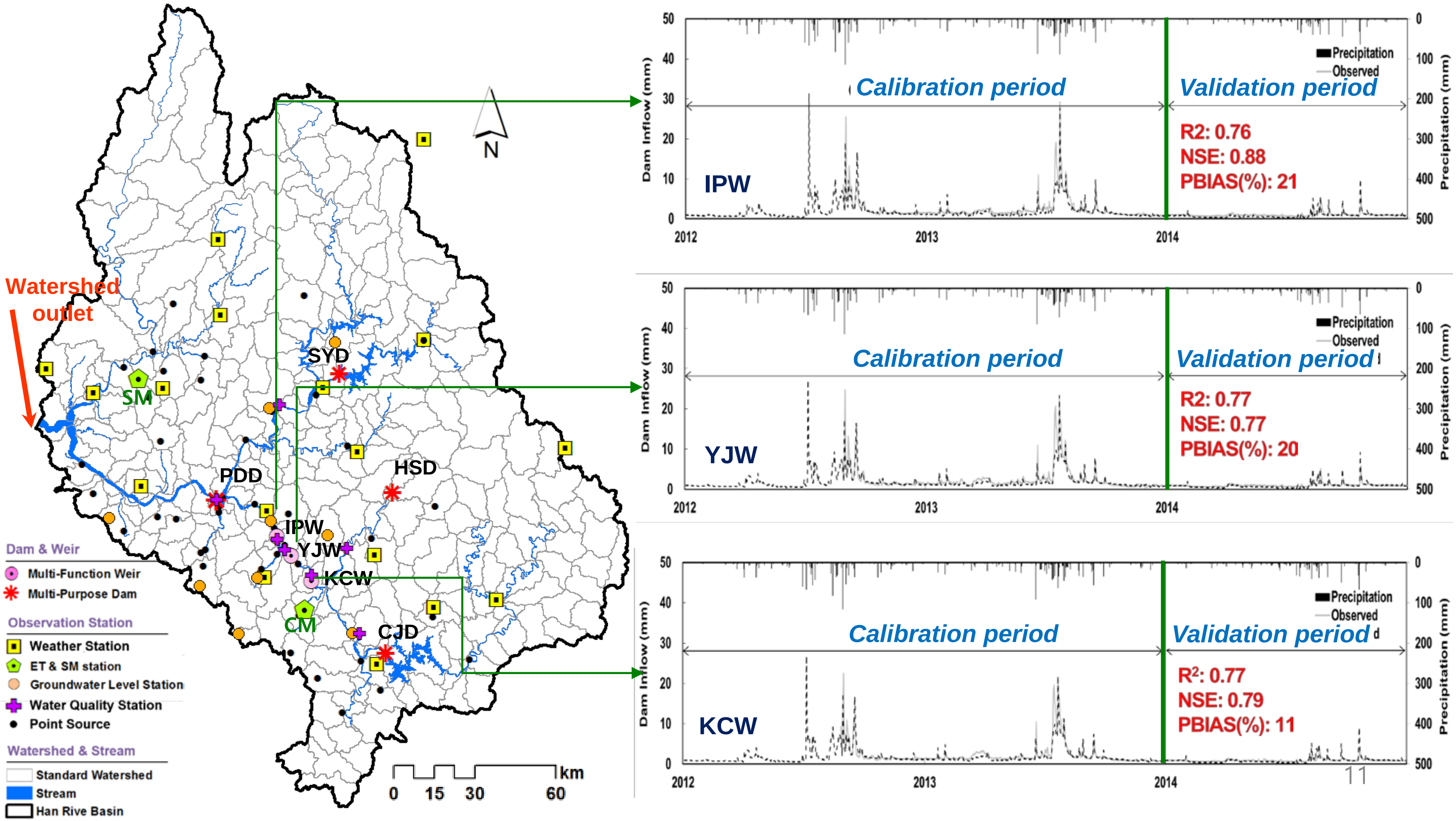


Model calibration and validation

Ahn et al., (2016)

Observed vs. simulated streamflow results of model calibration and validation

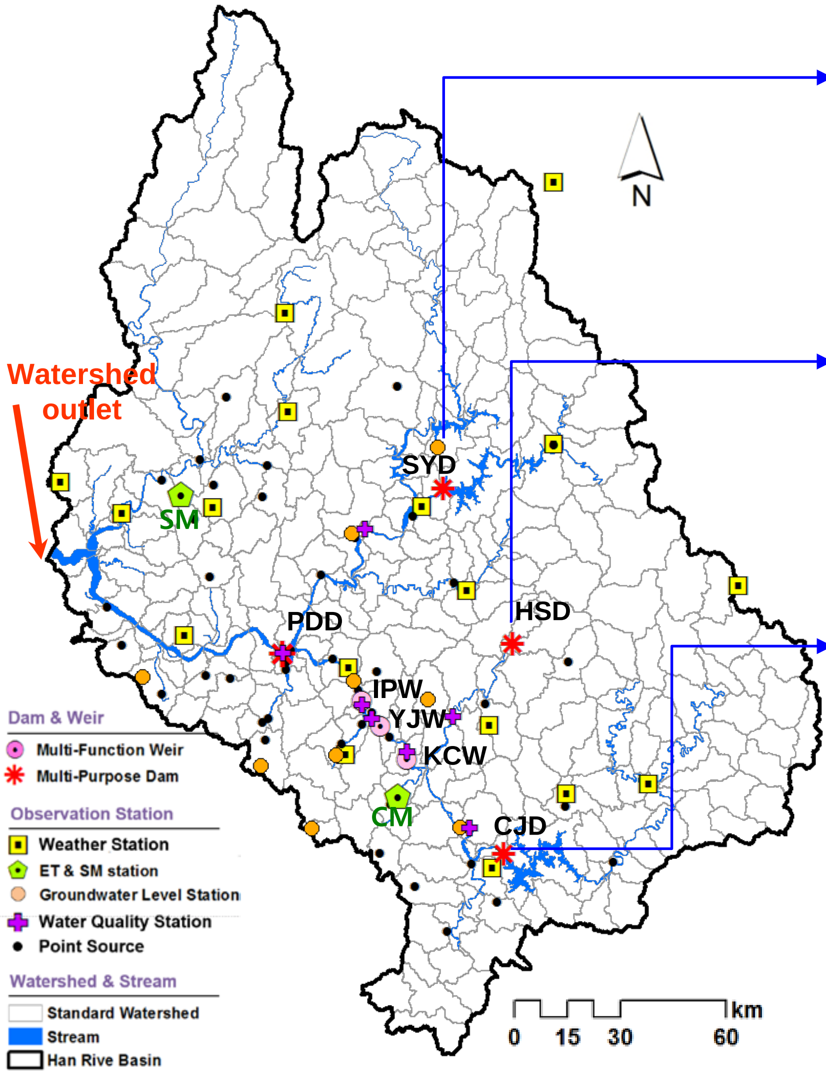
- ✓ **Calibration : 2 years (2012-2013) / Validation : 1 year (2014)**

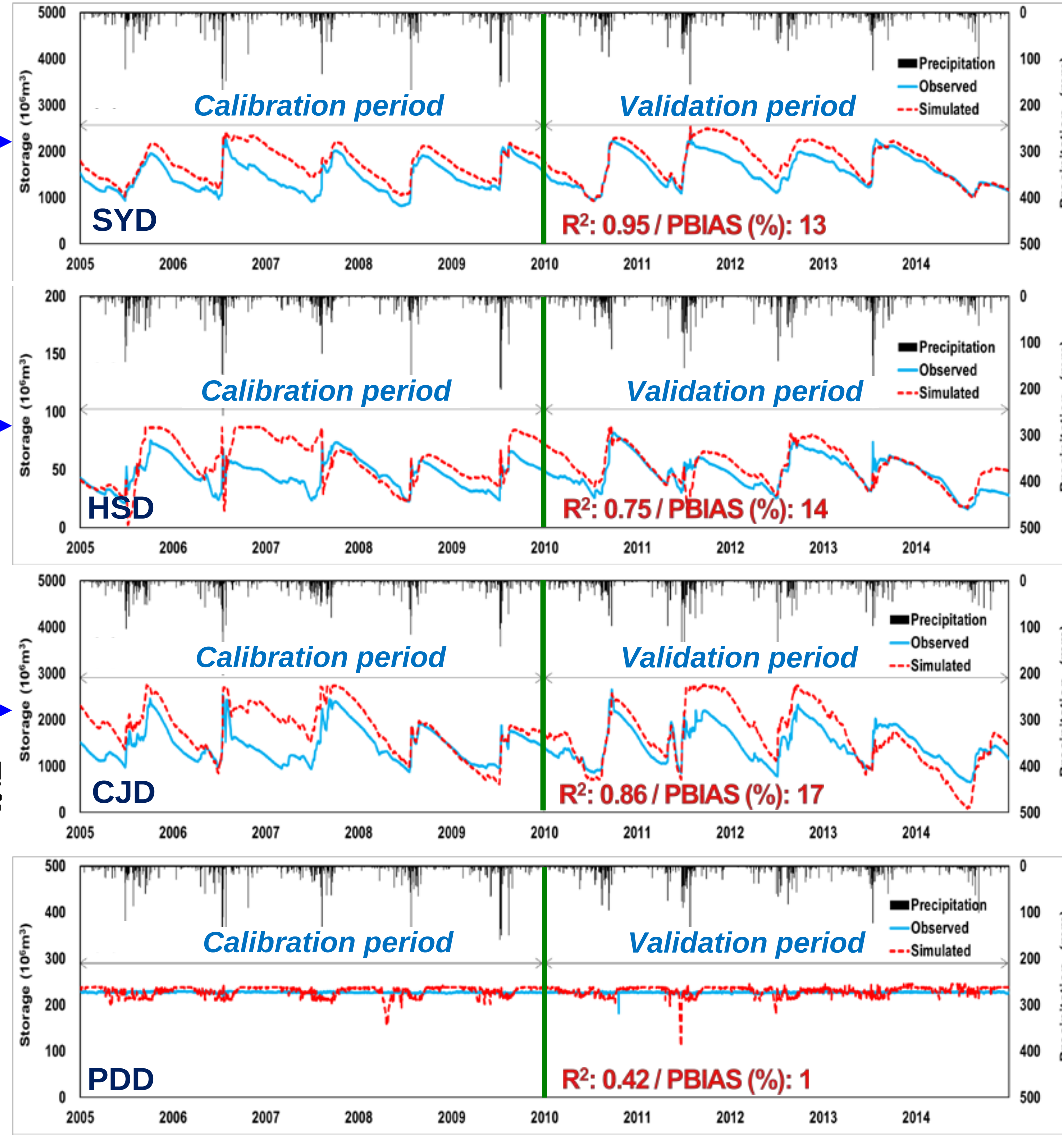


Model calibration and validation

Ahn et al., (2016)

Fitted results of 4 multipurpose dams storage



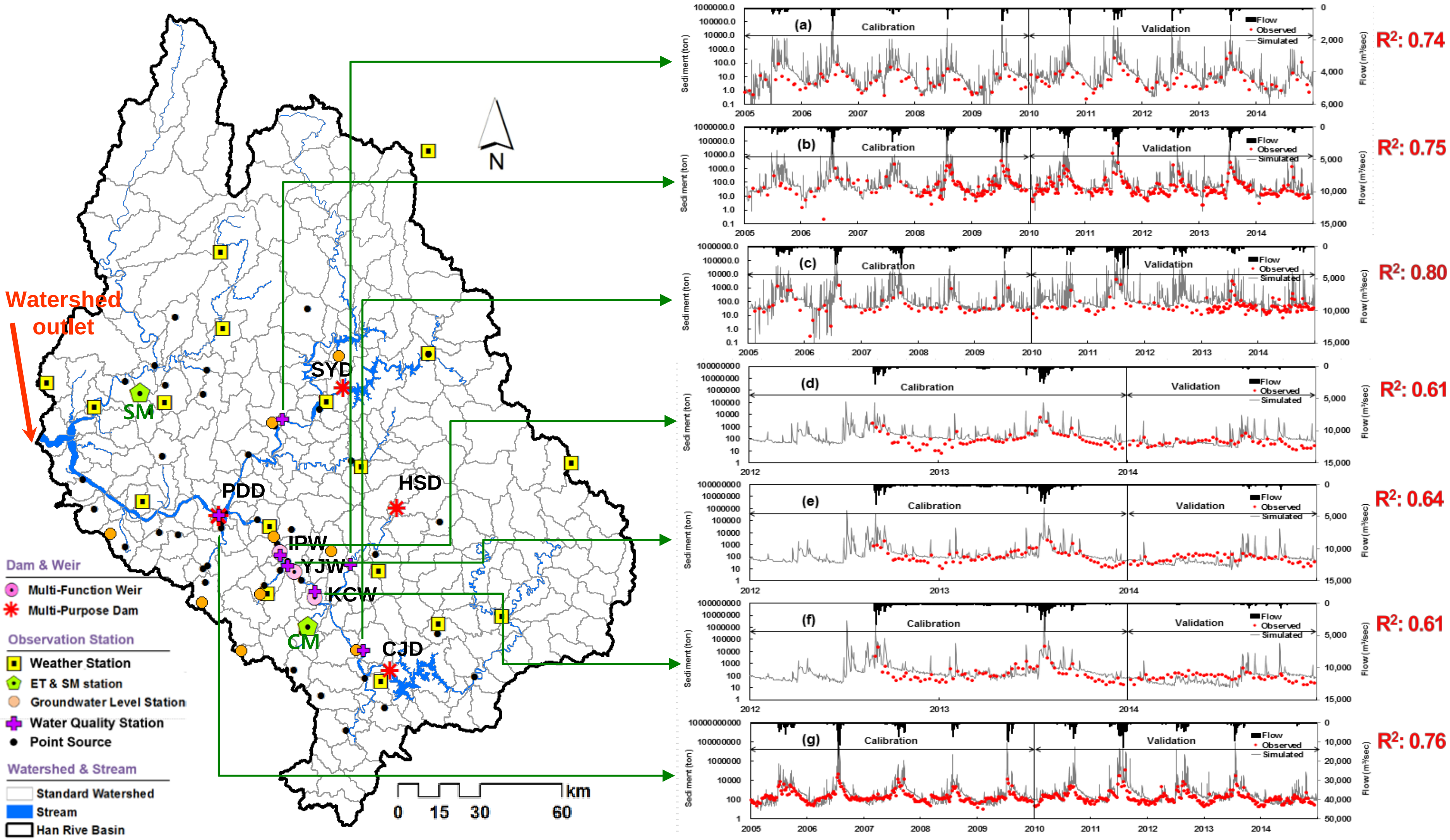


Model calibration and validation

Ahn et al., (2016)

Observed vs. simulated <u>sediment</u> results of SWAT model calibration and validation

✓ Calibration : 5 years (2005-2009) / Validation : 5 years (2010-2014)

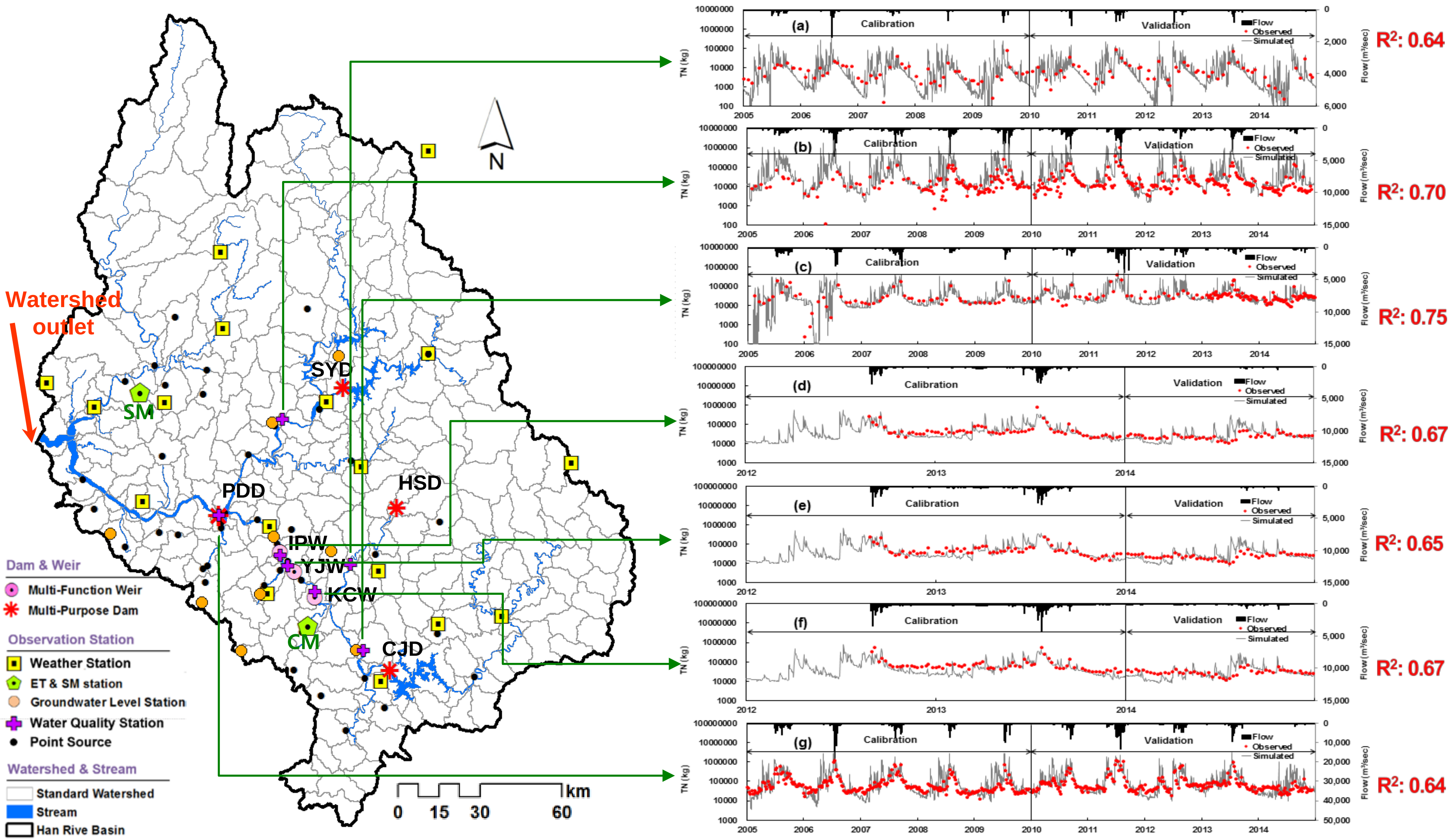


Model calibration and validation

Ahn et al., (2016)

Observed vs. simulated T-N results of SWAT model calibration and validation

✓ Calibration : 5 years (2005-2009) / Validation : 5 years (2010-2014)

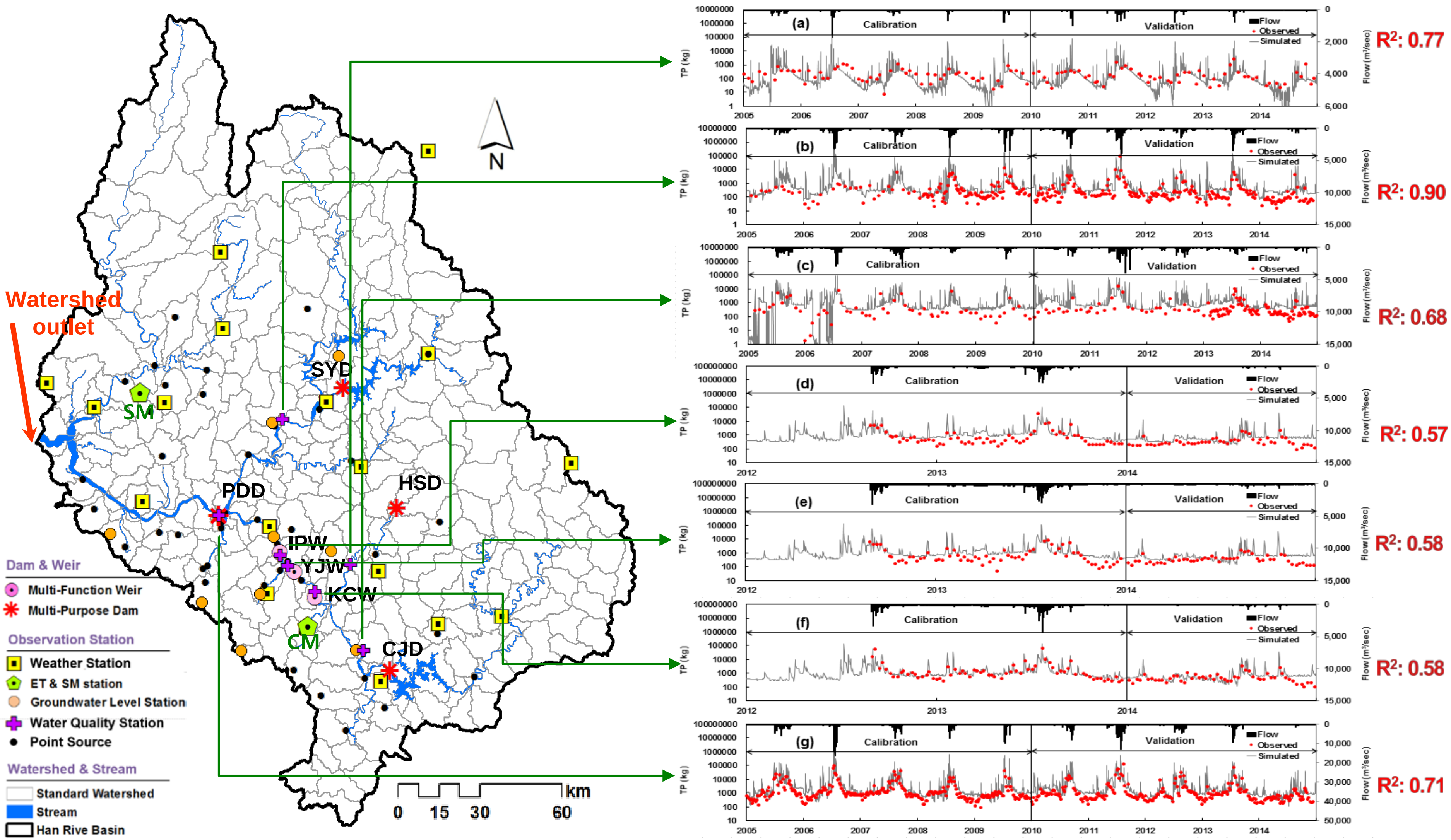


Model calibration and validation

Ahn et al., (2016)

Observed vs. simulated T-P results of SWAT model calibration and validation

✓ Calibration : 5 years (2005-2009) / Validation : 5 years (2010-2014)

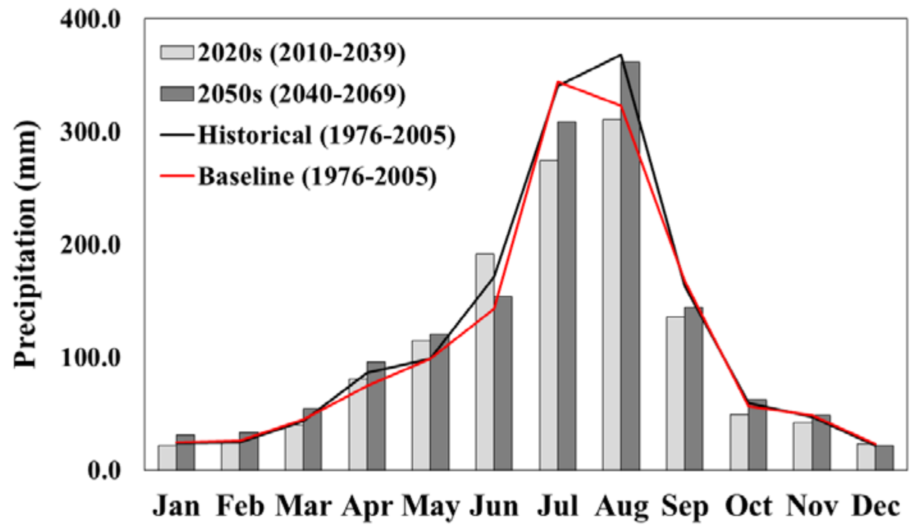


Climate Change Scenario

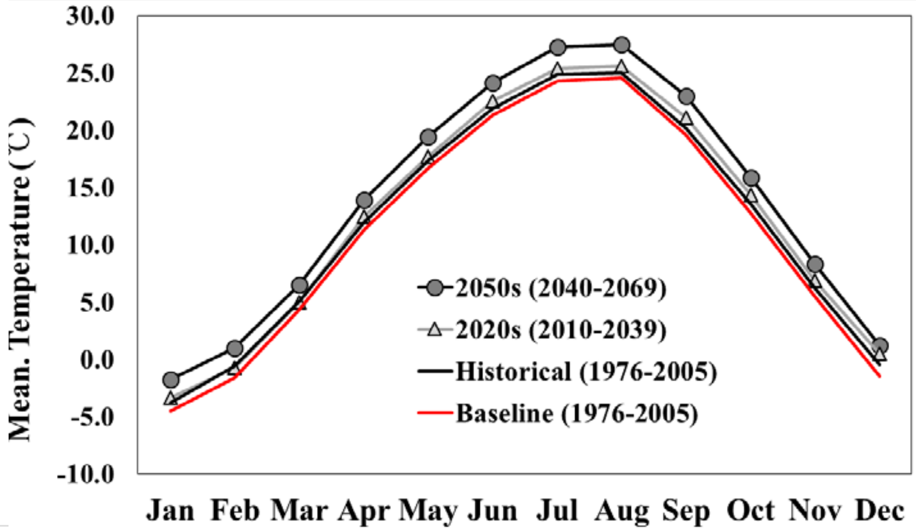
HadGEM3-RA RCP 8.5

✓ **2010-2019 / 2010-2029 / 2010-2039 / 2010-2049 / 2010-2059 / 2010-2069**

Precipitation



Mean. Temperature

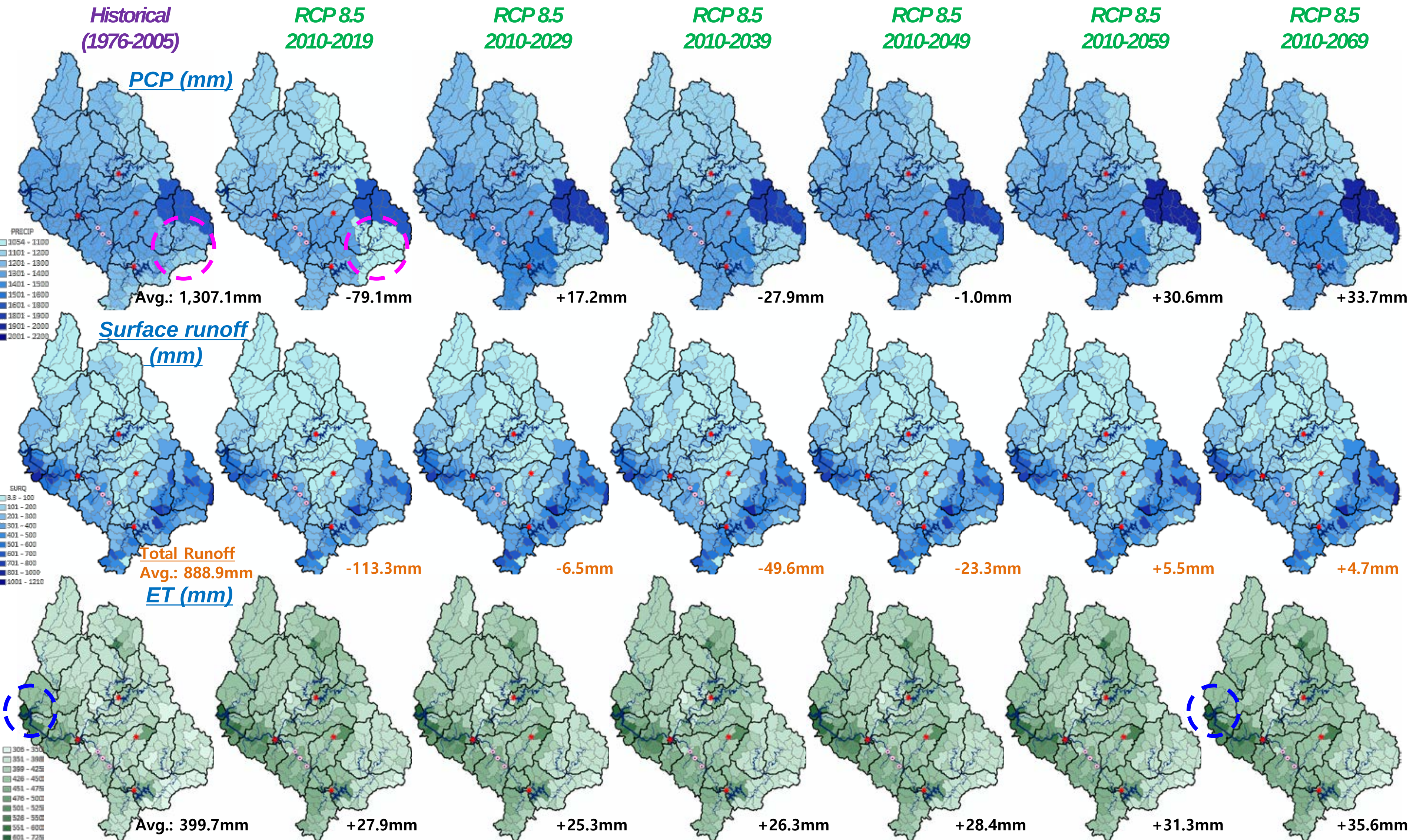


	Historical (1976-2005)	2010-2019	2010-2029	2010-2039	2010-2049	2010-2059	2010-2069
PCP (mm)	1,447.6	1,256.6 (-191.0)	1,352.4 (-95.2)	1,319.3 (-128.3)	1,342.5 (-105.1)	1,347.9 (-72.7)	1,376.9 (-70.7)
Mean T (℃)	11.8	11.9 (+0.1)	12.1 (+0.3)	12.3 (+0.5)	12.5 (+0.7)	12.8 (+1.0)	13.1 (+1.3)

Assessment of Climate Change

Decade Accumulative Assessment

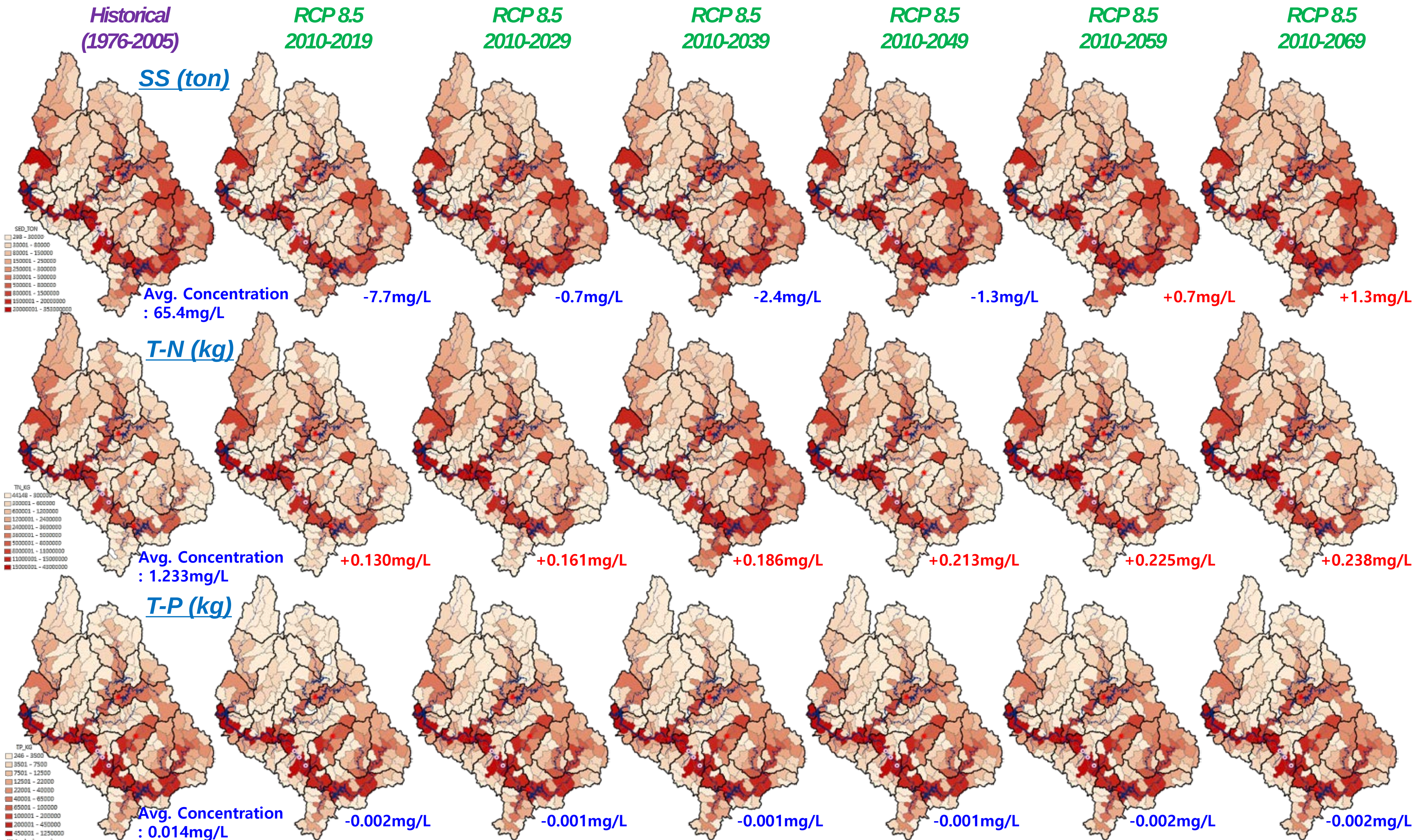
✓ **Precipitation, Surface runoff and Evapotranspiration**



Assessment of Climate Change

Decade Accumulative Assessment

✓ **Water Quality (Sediment, T-N, T-P)**



Data Collection

Watershed Health Components (introduced by U.S. EPA)

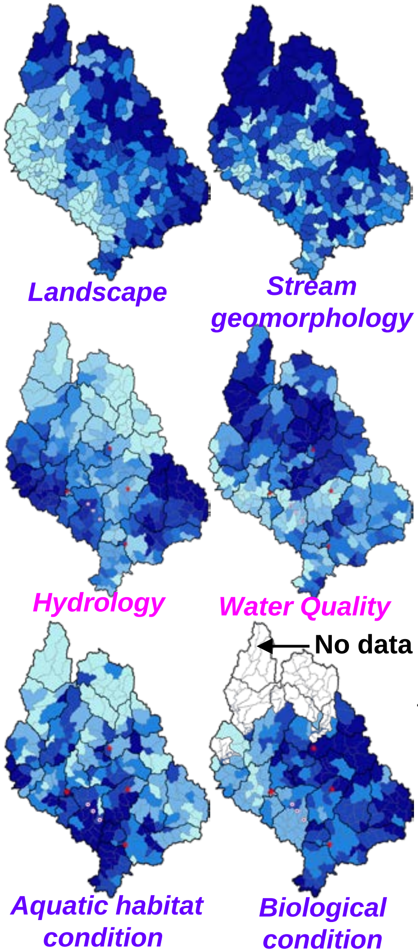
Watershed Health Components (introduced by U.S. EPA)

✓ **To analyze the effects of hydrology and water quality on watershed health**

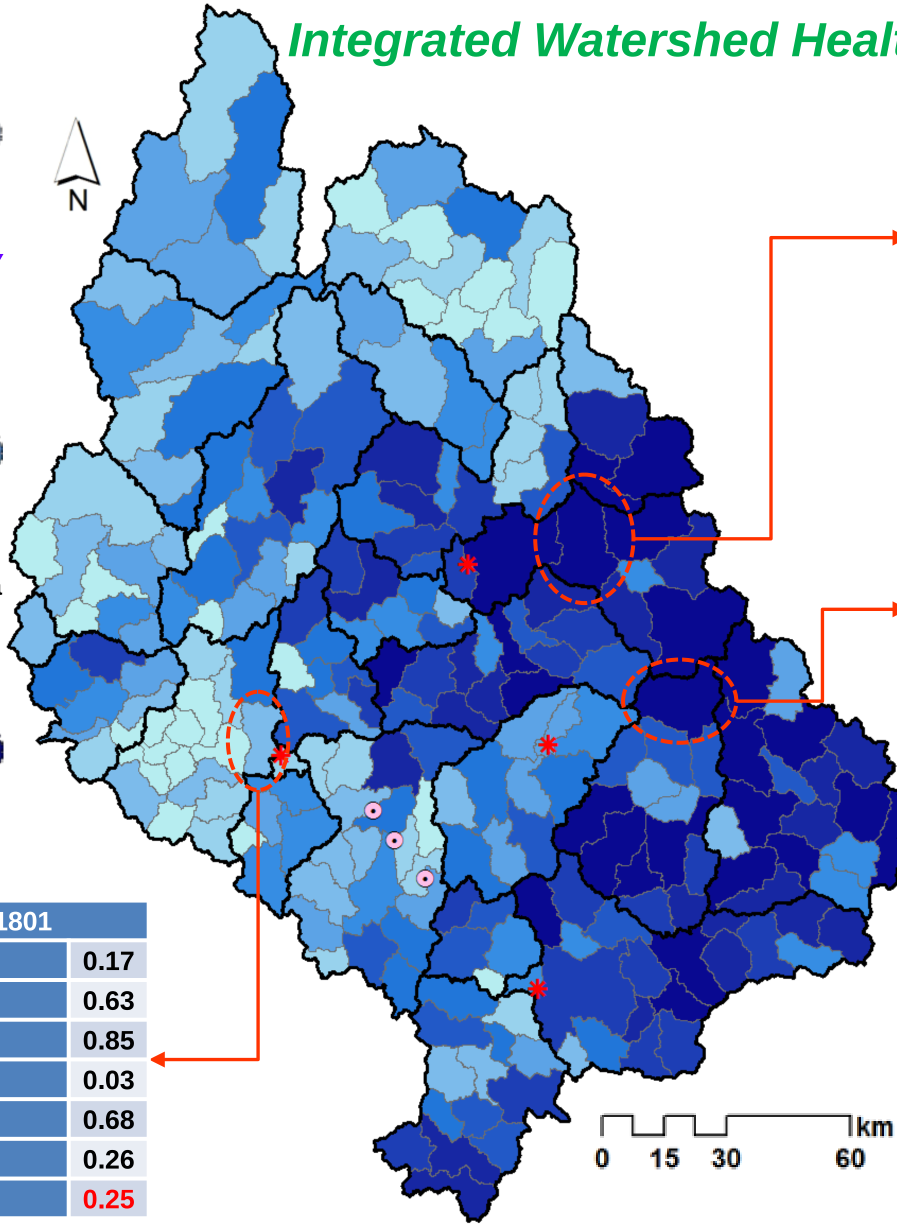
Component (metric)		How measured	Dataset	
Integrated capacity metrics (watershed health)				
Landscape	Green area	Percentage of watershed occupied by natural land cover	GIS data	Land cover 2008[a]
	Active river area	Percentage of natural land cover within the Active River Area		Land cover 2008, stream[b]
Geomorphology	Stream geomorphology	Percentage of assessed stream length in the reference condition	GIS data	SRTM DEM (90×90)[c], stream
Hydrology	Total	Precipitation and total runoff storage ratio	SWAT modeling data (1984–2015)[d]	PREP, TQ
	Surface processes	Surface runoff storage ratio		SQ
	Soil water dynamics	Infiltration, soil water and lateral flow storage ratio		INFILT, SW, LQ
	Groundwater dynamics	Percolation, groundwater recharge and return flow storage ratio		PERCOL, RECHARGE, GWQ
Water quality	Water quality	Percentage of assessed value in the reference criteria	SWAT modeling data (1984–2015)	Sediment, T-N, T-P
Aquatic habitat conditions	Habitat connectivity	Reservoir density (number of reservoirs per stream length)	GIS data	Reservoir location map[e], stream
	Wetland	Percentage of watershed occupied by wetlands		Land cover 2008
Biological conditions	Biological	Percentage of assessed score in the reference condition	Monitoring data (2008–2013)[f]	TDI, BMI, FAI

Watershed Health

Ahn et al., (2016)



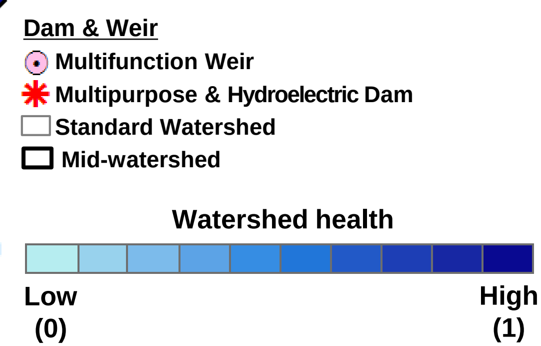
Integrated Watershed Health Index



Standard watershed 101206	
Landscape	0.89
Stream geomorphology	0.94
Hydrology	0.06
Water quality	0.77
Aquatic habitat condition	0.90
Biological condition	0.91
Integrated watershed health	1.00

Standard watershed 100201	
Landscape	0.66
Stream geomorphology	0.93
Hydrology	0.96
Water quality	0.10
Aquatic habitat condition	0.28
Biological condition	0.83
Integrated watershed health	0.91

Standard watershed 101801	
Landscape	0.17
Stream geomorphology	0.63
Hydrology	0.85
Water quality	0.03
Aquatic habitat condition	0.68
Biological condition	0.26
Integrated watershed health	0.25

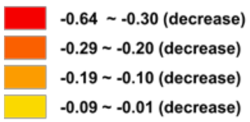


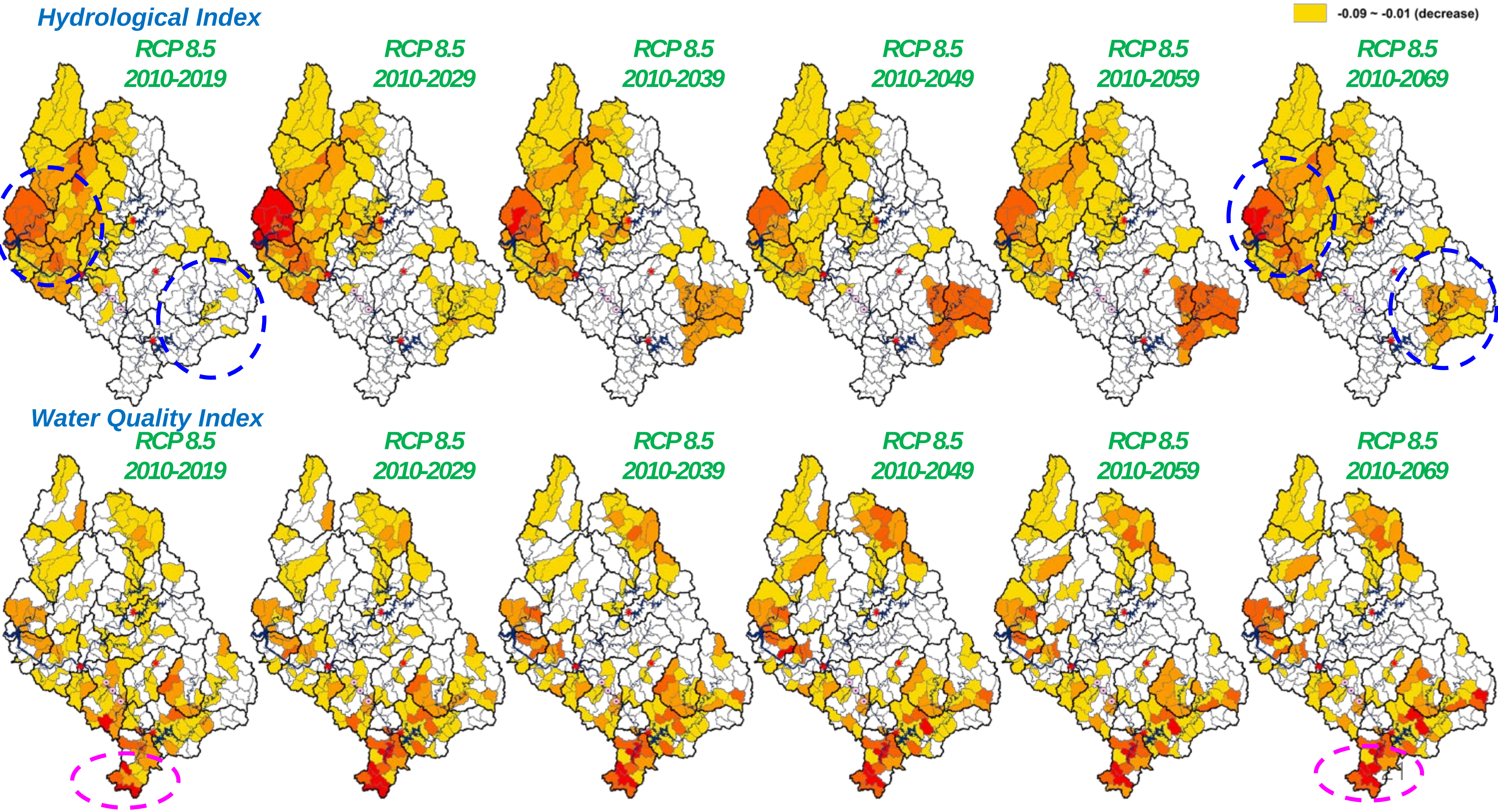
Assessment of Climate Change

<u>Decade Accumulative Assessment</u>

- hydrology was mainly affected by the future temperature and rainfall changes
- water quality was dominantly affected by the sources of point and nonpoint pollution.

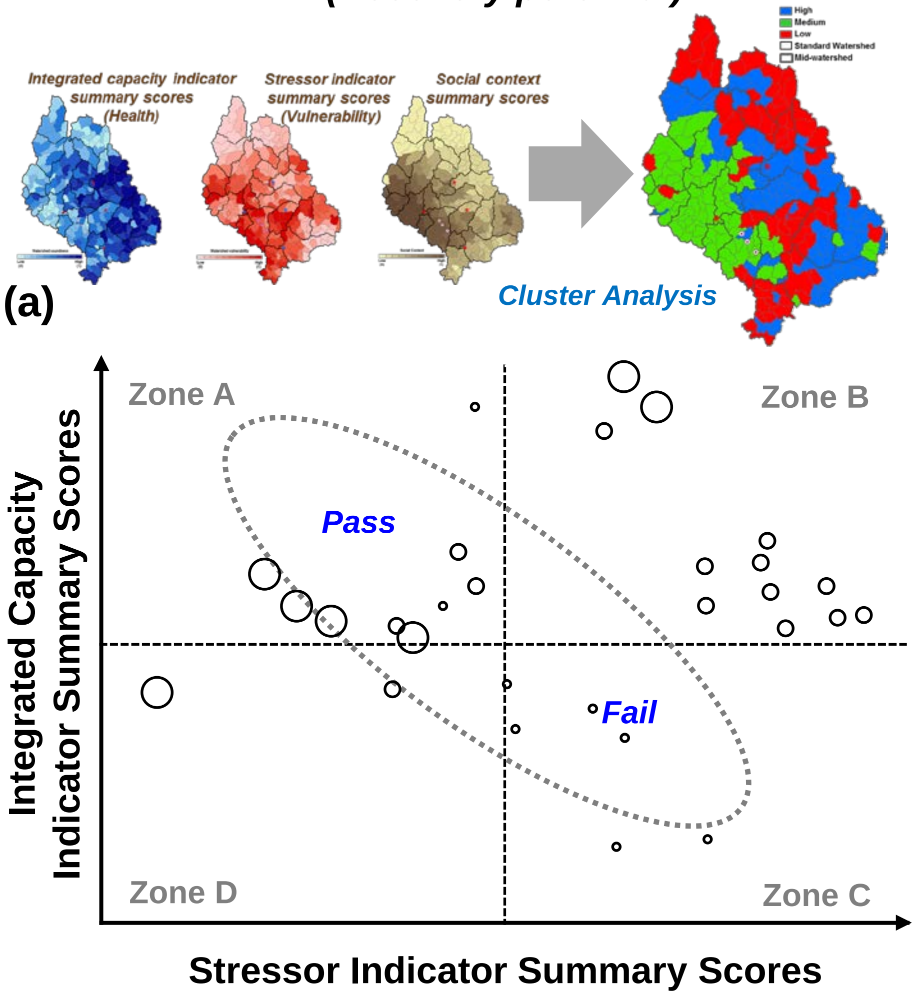
✓ Change Hydrological and Water Quality index from Historical (1975-2005)





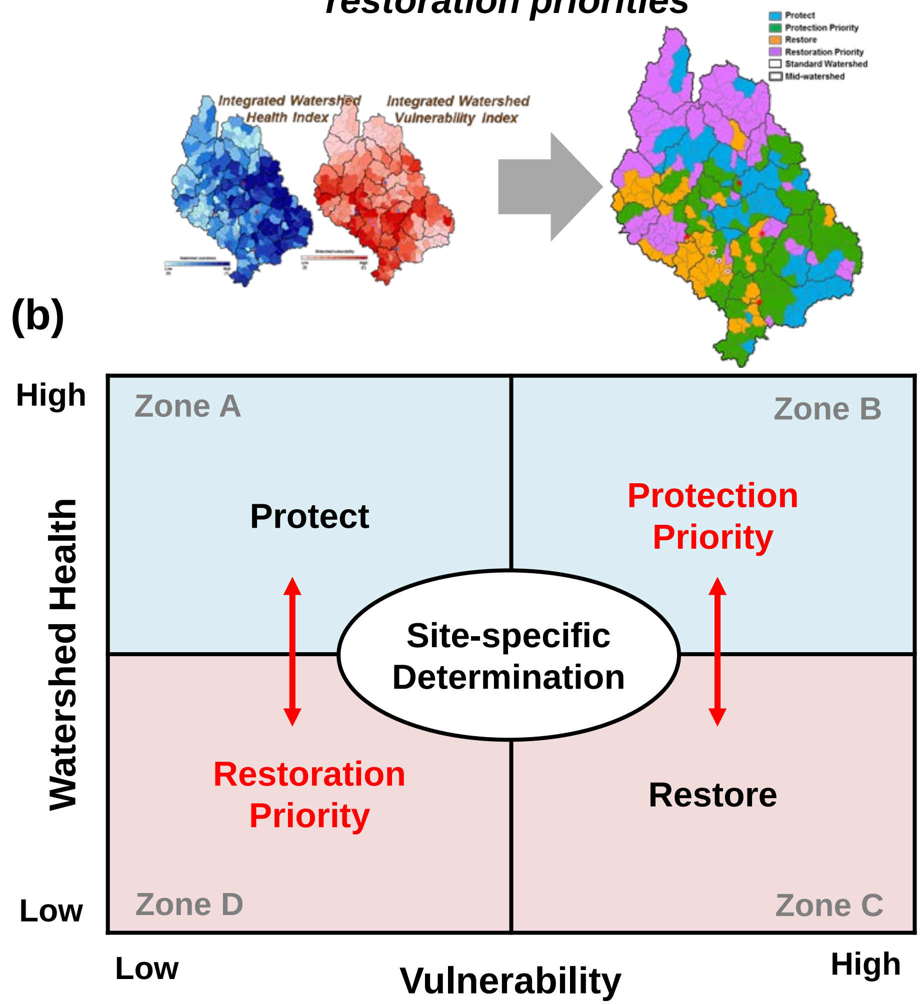
Watershed resilience and Priority

*Watershed **resilience analysis** (Recovery potential)*



*** Circle size increases with social context summary score value**

***Priorities matrix** for setting protection and restoration priorities*



Ref.) (Norton et al., 2009, A Method for Comparative Analysis of Recovery Potential in Impaired Waters Restoration Planning. Environmental Management 44:356-368.

Ref.) U.S. EPA. 2012, Identifying and Protecting Healthy Watersheds: Concepts, Assessments, and Management Approaches. EPA 841-B-11-002.

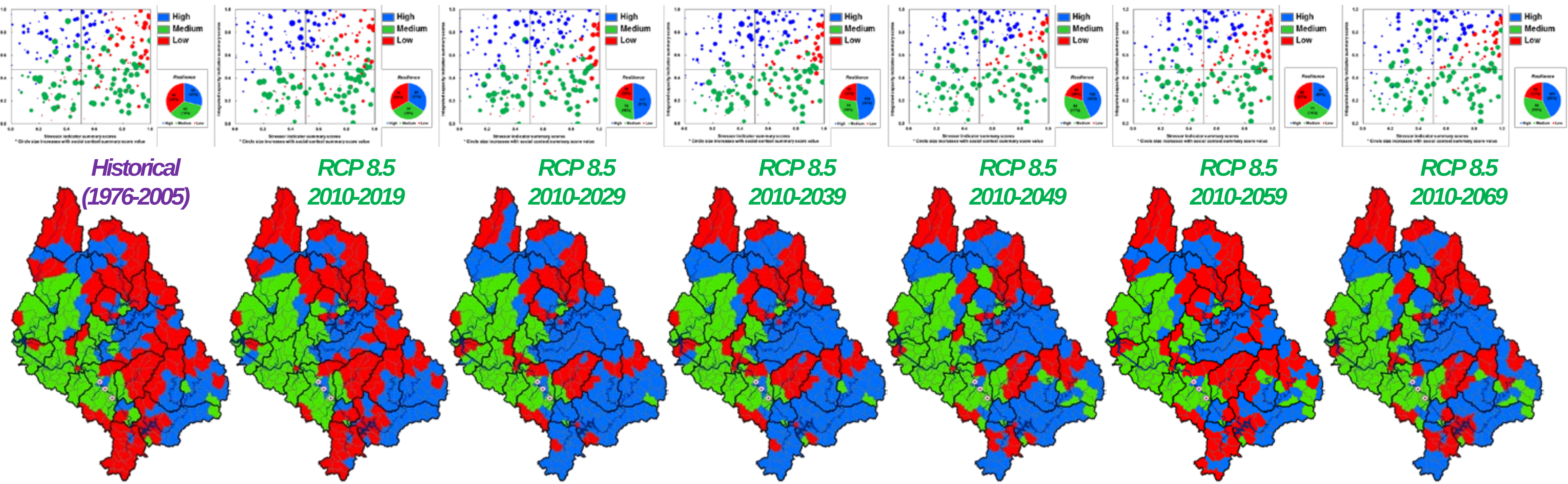
Assessment of Climate Change

Decade Accumulative Assessment

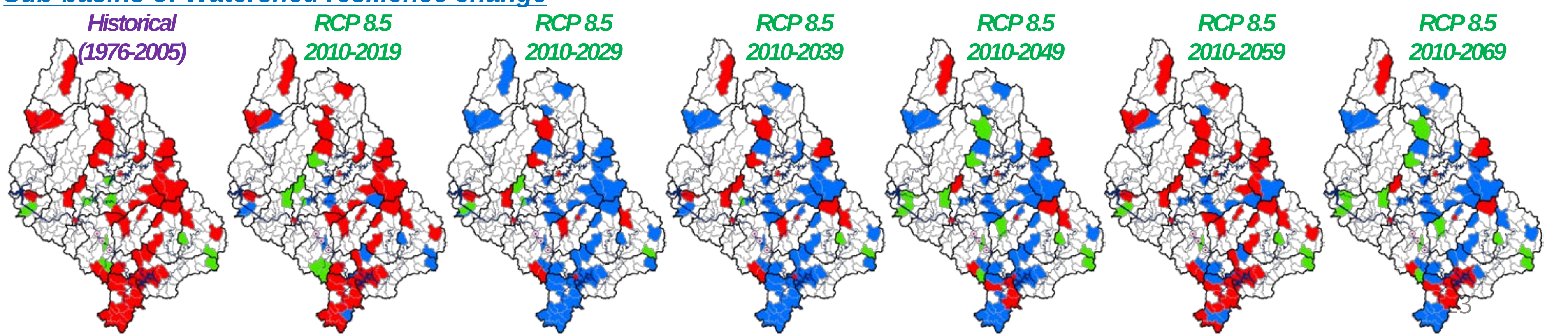
High
Medium
Low
Standard Watershed
Mid-watershed

✓ Watershed resilience(recovery potential) from Historical (1975-2005) to 2069

Watershed resilience



Sub-basins of Watershed resilience change



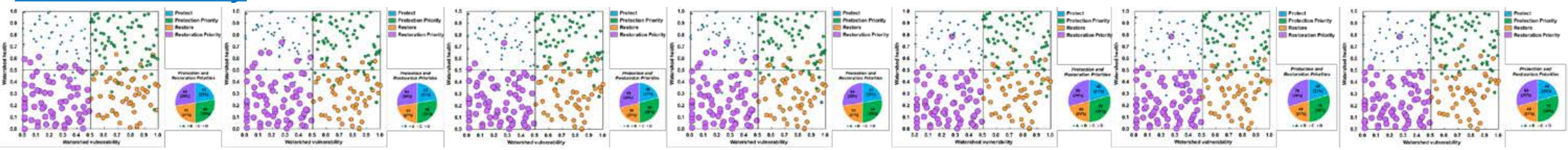
Assessment of Climate Change

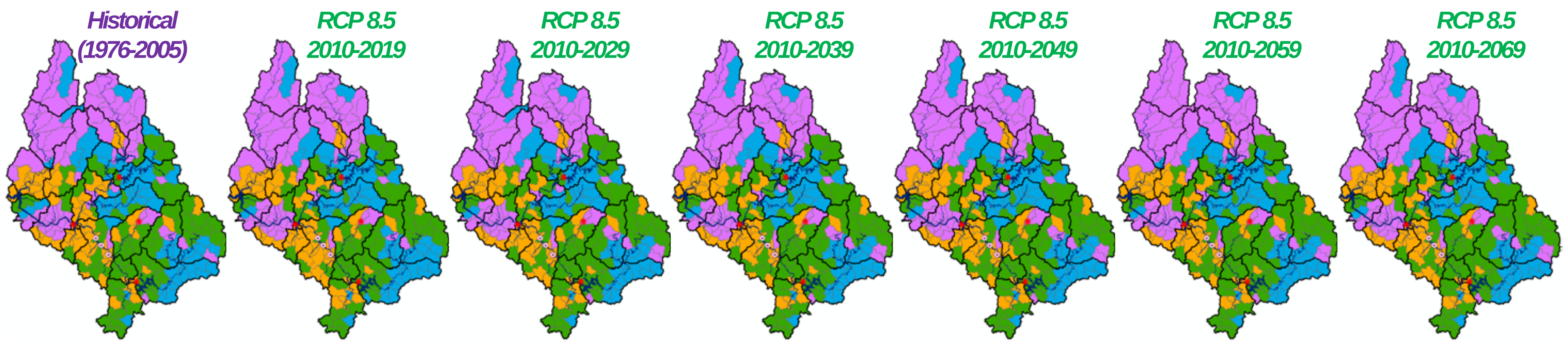
Decade Accumulative Assessment

- Protect
- Protection Priority
- Restore
- Restoration Priority
- Standard Watershed
- Mid-watershed

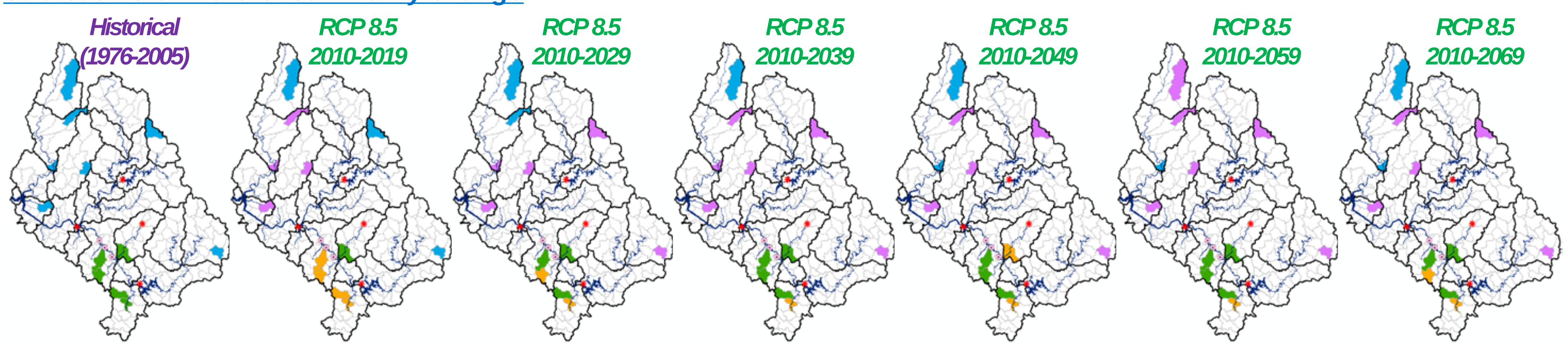
✓ **Watershed Protection and Restoration priority from Historical (1975-2005) to 2069**

Watershed Priority





Sub-basins of Watershed Priority change



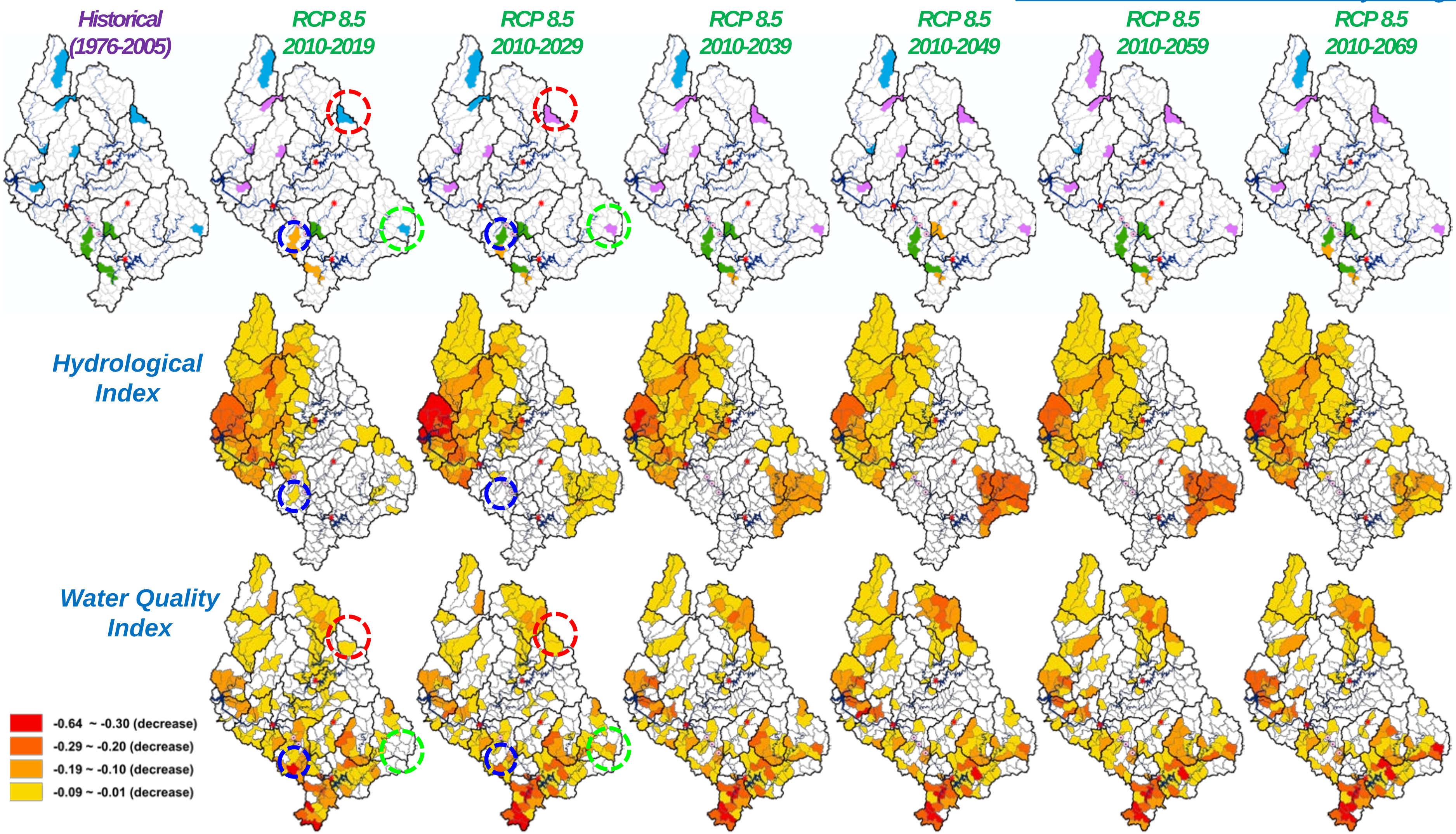
Assessment of Climate Change

- Protect
- Protection Priority
- Restore
- Restoration Priority
- Standard Watershed
- Mid-watershed

Decade Accumulative Assessment

✓ **Watershed Priority, Hydrological Index, and Water quality changes**

Sub-basins of Watershed Priority change



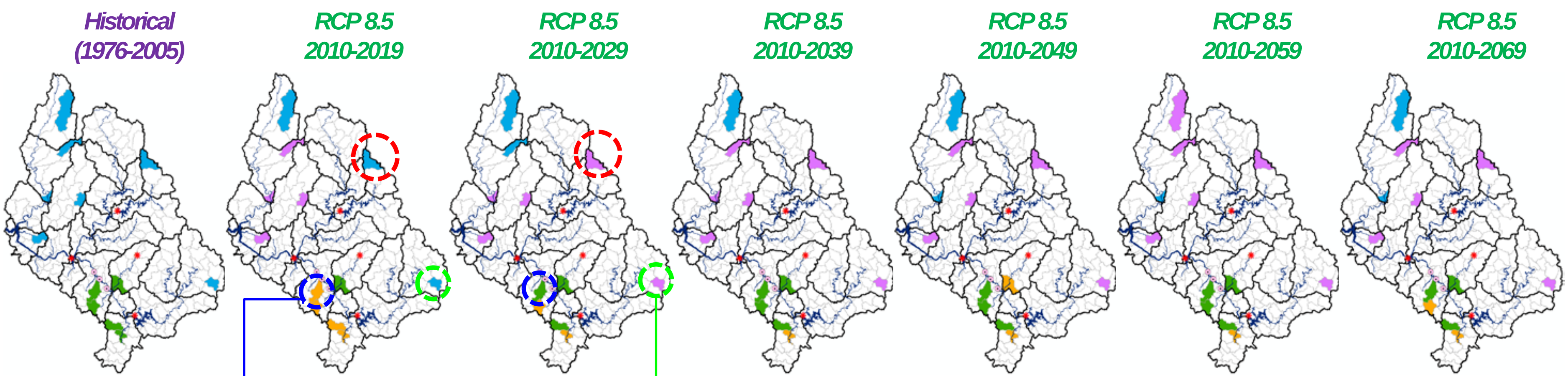
Assessment of Climate Change

Protect
Protection Priority
Restore
Restoration Priority
Standard Watershed
Mid-watershed

Decade Accumulative Assessment

✓ Watershed Priority changes of decade

Watershed Priority change sub-basin



- **Short term (~2019)**
  Restore
- **Medium and Long term (~2069)**
  Protection Priority

- **Short term (~2019)**
  Protect
- **Medium and Long term (~2069)**
  Restoration Priority

- **Create clear roadmaps for different time periods and need timely evaluation.**
- **It is necessary to implement a focused investment for vulnerable districts as a preventive measure, and clarify measures or places to invest first.**
- **The watershed restoration priorities of the climate change adaptation plan should be verified based on short term assessment results, but prospects for verification action plan should based on long-term observation.**

Summary and Conclusion

- **This study designed to investigate projected results of future time periods by using a decadal accumulative evaluation.**
  - The **watershed health assessment** of Han River basin in South Korea was performed using monitoring data and **SWAT modeling results.**
  - The six essential indicators were used to the healthy watersheds assessment approach: 1) landscape condition, 2) geomorphology, 3) hydrology, 4) water quality, 5) habitat, and 6) biological condition.
  - Especially, the sub-index for hydrology and water quality on watershed health is developed to assess for a possible **decade accumulative changes** analysis in watershed using SWAT modeling results.

- **From the results of a decadal accumulative evaluation from 2010-2019 to 2010-2069, we found that this kind of evaluation can provide more insight and better identify processes for the spatiotemporal changes in hydrology and water quality behavior that will occur in near-term future time periods.**

- **We intend to further study and adapt climate change-based algorithms for the watershed health of nationwide. We feel that further work on the management approaches to integrated watershed assessment will support decision making by national and local governments.**

Thank You

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