Research on Optimal Management Measures at Multiple Scales in the Jinjiang River Basin under the Background of Climate Change

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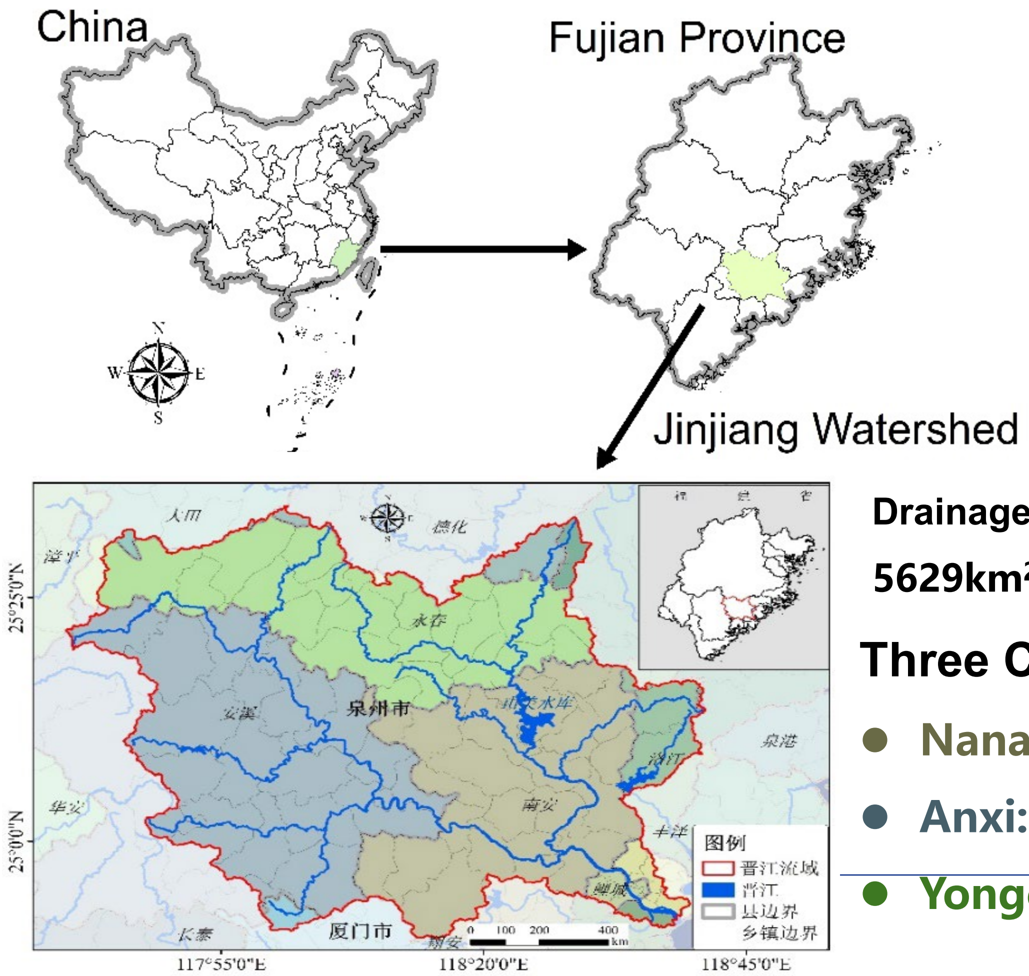
Background: research area

Jinjiang Watershed



Drainage Area:

5629km²

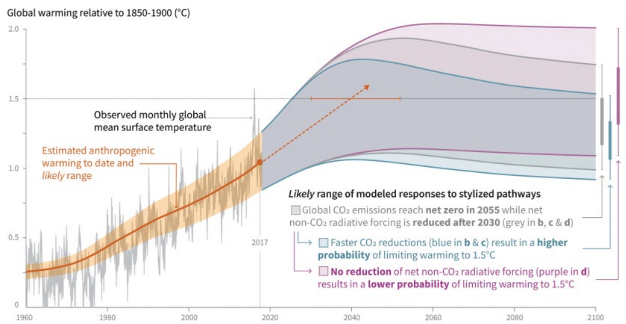
《2018 Fujian Province Water Resources Bulletin》:
164 km < Class III water standards
30.9% of the total evaluated river length

Research Significance:
Improving watershed environmental conditions
ensuring high-quality sustainable development

Three Counties:

- **Nanan: Tea**
- **Anxi: Tea**
- **Yongchun: Orchards, Tea**

Background: Climate change



Impacts on watersheds

- Alter the physicochemical processes of nutrient cycling and hydrological cycles in watersheds.
- More frequent floods, increased soil erosion, and aggravated water eutrophication in the watershed (Camici et al., 2014; Neupane & Kumar, 2015; Sunde et al., 2018)
- Critical source areas changes (Piniewski et al., 2021; Wagena & Easton, 2018; Xu et al., 2019)
- Climate change may undermine the effectiveness of current Best Management Practices (BMPs), especially in the latter part of the 21st century (Teshager et al., 2017). If managers wish to achieve the same water quality management goals while addressing climate change, they will need to incur higher costs (Plunge et al., 2022).

Contents

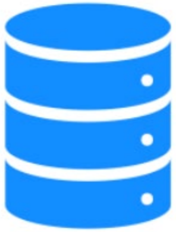
01 Research on Best Management Practices (BMPs) for Watersheds

- Do optimal watershed management measures have the same configuration at different spatial scales of management?

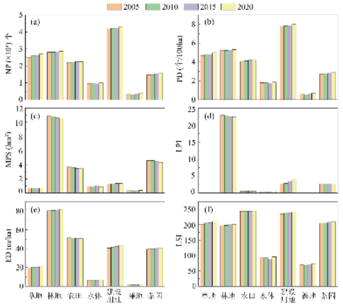
02 Future Impacts of Climate Change on BMPs

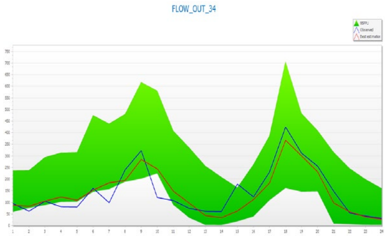
- Does climate change affect the implementation efficiency of optimal watershed management measures? Is there a management measure that can mitigate the effects of climate change?

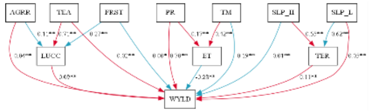
Part1

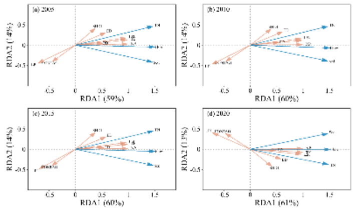


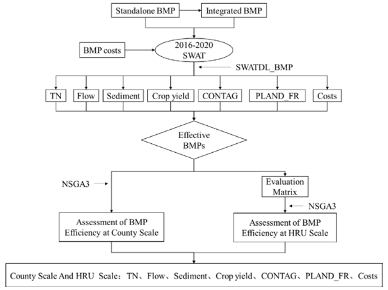
- 2001-2005
- 2006-2010
- 2011-2015
- 2016-2020

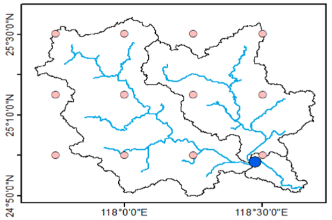


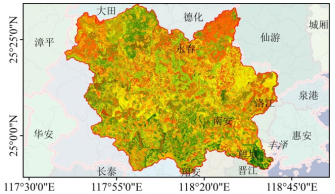












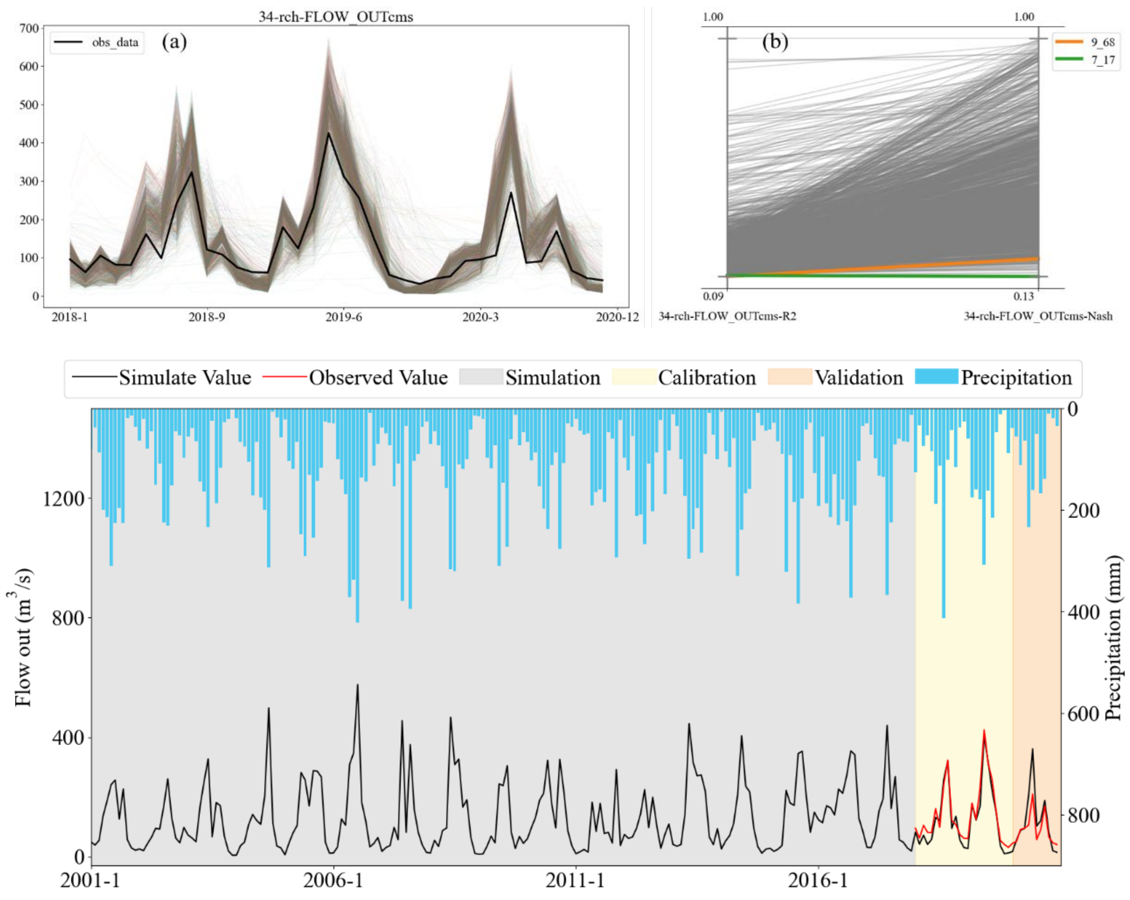
SWAT

Structural Equation Modeling (SEM)

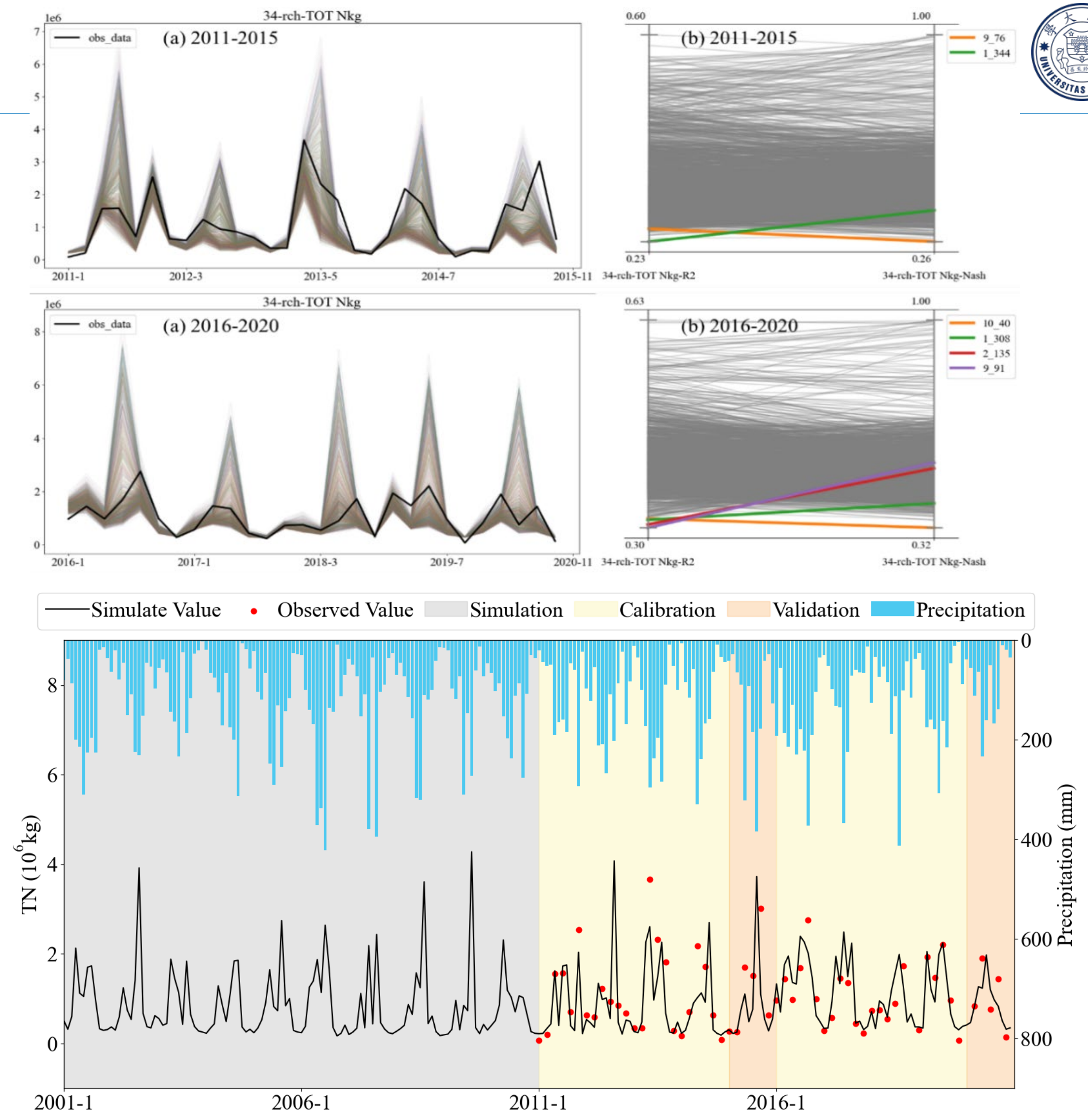
Redundancy Analysis(RDA)

SWAT BMP

Results: Calibration



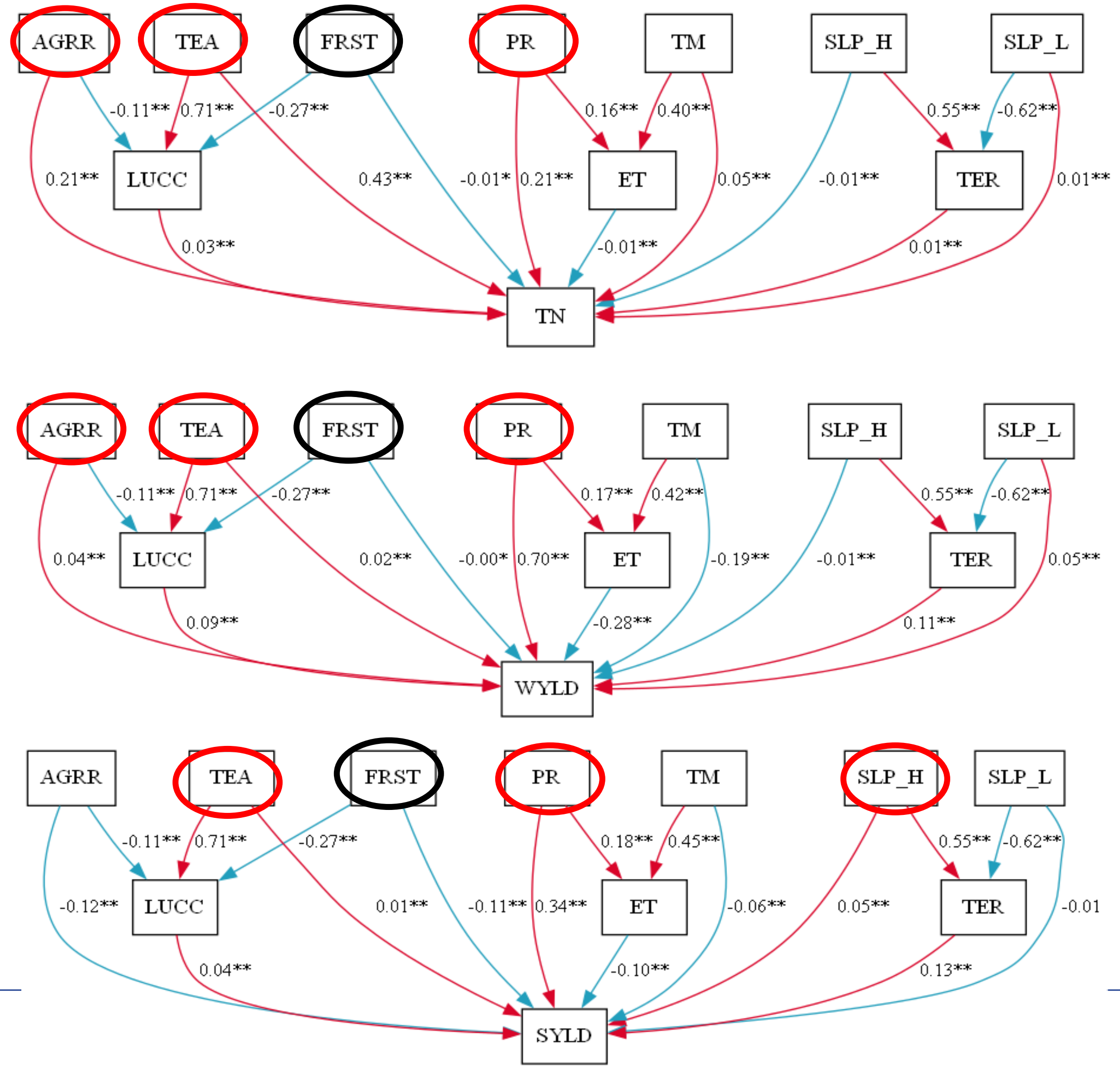
Results of runoff calibration and validation



Results of TN (Total Nitrogen) calibration and validation

Results: Hydrological and water quality drivers

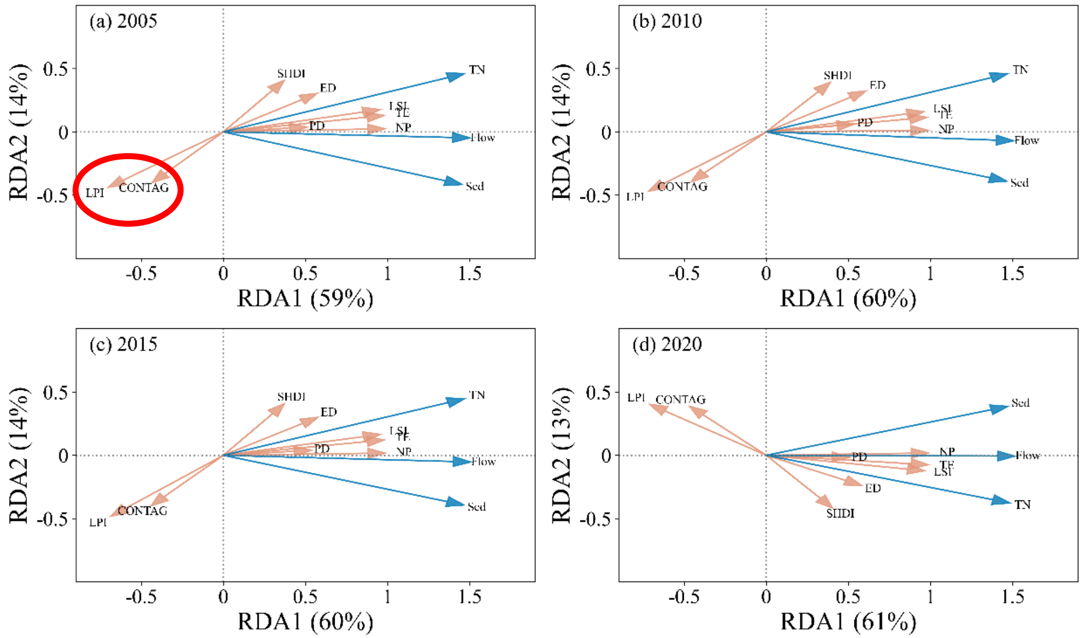
Environmental Factors

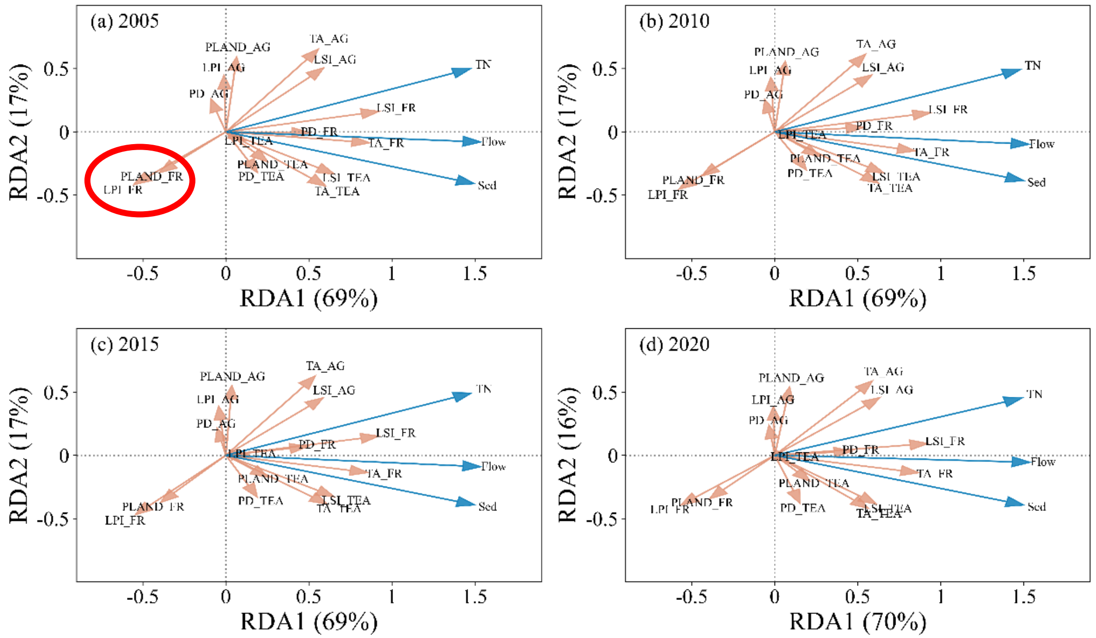


- Tea, farmland, and precipitation → TN and runoff
- Tea, precipitation, and steep slopes → sediment load
- The spatiotemporal distribution of forests inhibits changes in TN, runoff, and sediment load.

Results: Hydrological and water quality drivers

Landscape Factors





Landscape level：

- The fragmentation of watershed landscapes leads to deterioration in hydrological and water quality conditions.
  - ➢ LPI（Largest Patch Index)
  - ➢ CONTAG（Contagion Index)

Type level：

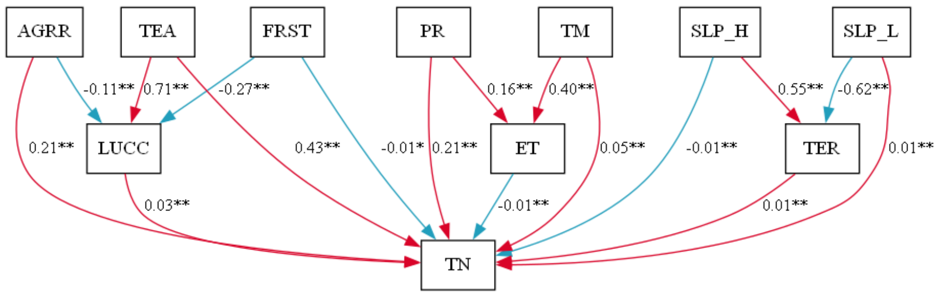
- The complexity of agricultural land area and shape, along with the fragmentation of forests, drives the deterioration of hydrological and water quality conditions in the watershed.
  - ➢ LPI_FR (Forest LPI)
  - ➢ PLAND_FR (Percentage of Landscape of Forest)

Results: BMP Design

Materials

- 2016-2020 SWAT

Design and Implementation Costs of BMPs



Independent BMPs

BMP_code	Measures	Contents
CFC1	Fertilizer Management (FC)	-10%
CFC2		-20%
CVF1	Vegetative Filter Strip (VF)	1m
CVF2		5m
CVF3		10m
CGW1	Grassed Waterway (GW)	1m
CRC1	Reforestation（RC)	Slope > 25°
CRC2		Slope >15°
CRC3		Slope >6°
CIR1	Intensive Irrigation（IR)	Improving Irrigation Efficiency
CRS1	Residue Management (RS)	100kg/hm^2
TFC1	Fertilizer Management (FC)	-10%
TFC2		-20%
TGW1	Grassed Waterway (GW)	1m
TRC1	Reforestation（RC)	Slope > 25°
TRC2		Slope >15°
TRC3		Slope >6°
SPD1	Sedimentation Pond (PD)	10% of Sub-watershed Area

0、Full permutation
1、RC
2、Same Type

Integrated BMPs

BMP_code	BMP	BMP_code	BMP
31	CFC2_CRS1	36	CVF2_CIR1
32	CVF1_CGW1	37	CVF3_CIR1
33	CVF2_CGW1	38	CVF1_CRS1
34	CVF3_CGW1	39	CVF2_CRS1
35	CVF1_CIR1	40	CVF3_CRS1
。。。	。。。	。。。	。。。

Results: BMP costs

Materials

- 2016-2020SWAT

Design and Implementation Costs of BMPs

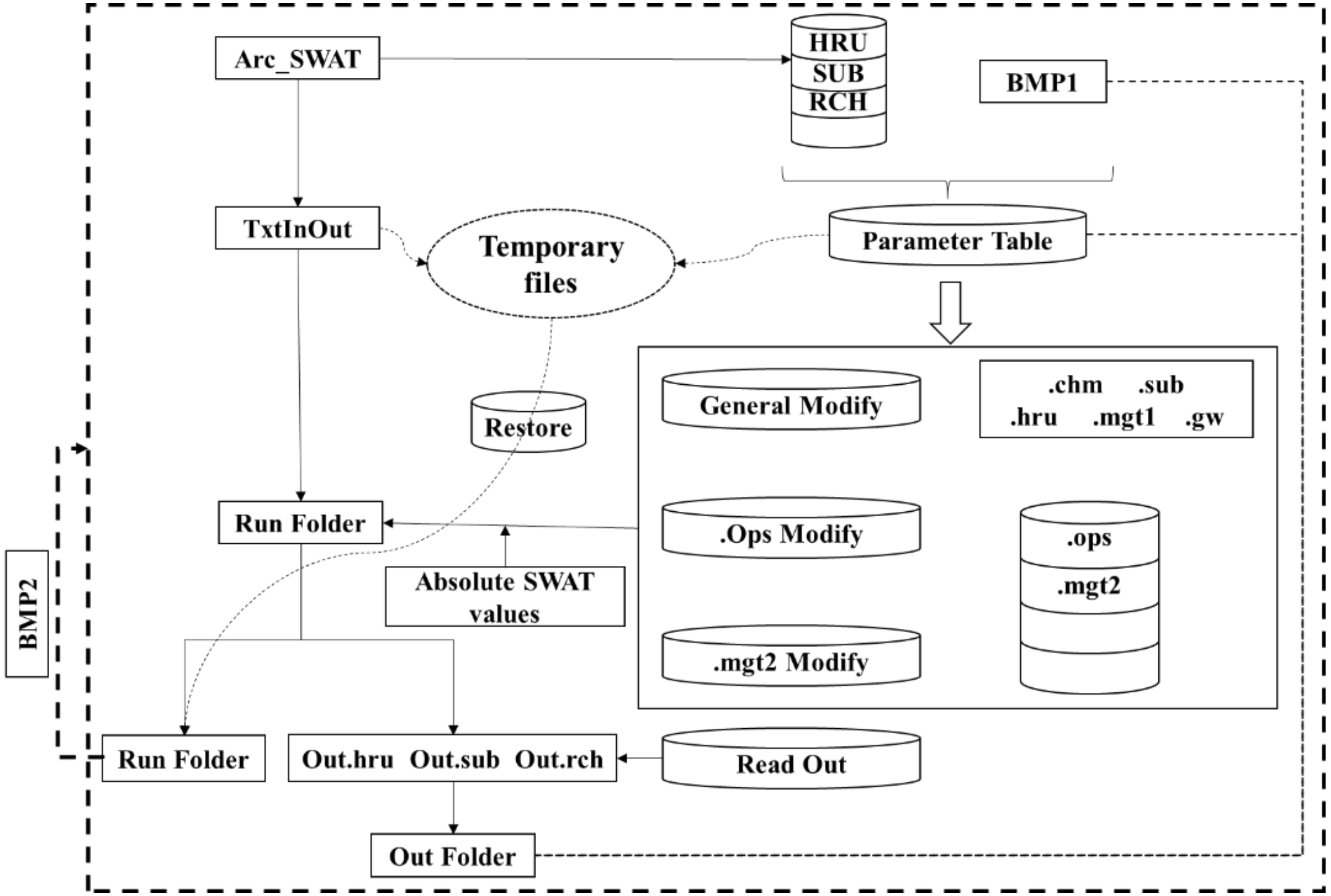
$$C_{td}(¥\cdot ha^{-1}\cdot a^{-1}) = C_0\left[(1+s)^{td} + rm\left[\frac{(1+s)^{td}-1}{s}\right]\right]/t\,d$$

C_{td} represents the total cost of each BMP ($¥/ha/a$) , C_0 represents the construction cost of each BMP ($¥/ha/a$) , represents the maintenance cost of each BMP , s represents the fixed annual interest rate, with 6% being used as the fixed annual interest rate of the Bank of China, td represents the operational period of the BMP.

Code	Landuse	BMP name	Cost (¥)	unit
CFC1	AGRR	Fertilizer Management	−0.019	m^2
CFC2			−0.039	m^2
CVF1		Vegetative Filter Strip	20	m
CVF2			30	m
CVF3			61	m
CGW1		Grassed Waterway	61	m
CRC1		Reforestation	2.5	m^2
CRC2			2.5	m^2
CRC3			2.5	m^2
CIR1		Intensive Irrigation	0.009	m^2
CRS1		Residue Management	0	m^2
TFC1	TEA	Fertilizer Management	−0.021	m^2
TFC2			−0.42	m^2
TGW1		Grassed Waterway	61	m
TRC1		Reforestation	2.5	m^2
TRC2			2.5	m^2
TRC3			2.5	m^2
SPD1	Subbasin	Sedimentation Pond	400	m^3

Results

SWATDL_BMP



SWATDL_BMP

Simulation Scale
- Basin_BMP
- Subbasin_BMP
- Hru_BMP

Management Objectives
- SWAT_output
- Ecosystem Service Value
- Landscape Change
- 。。。

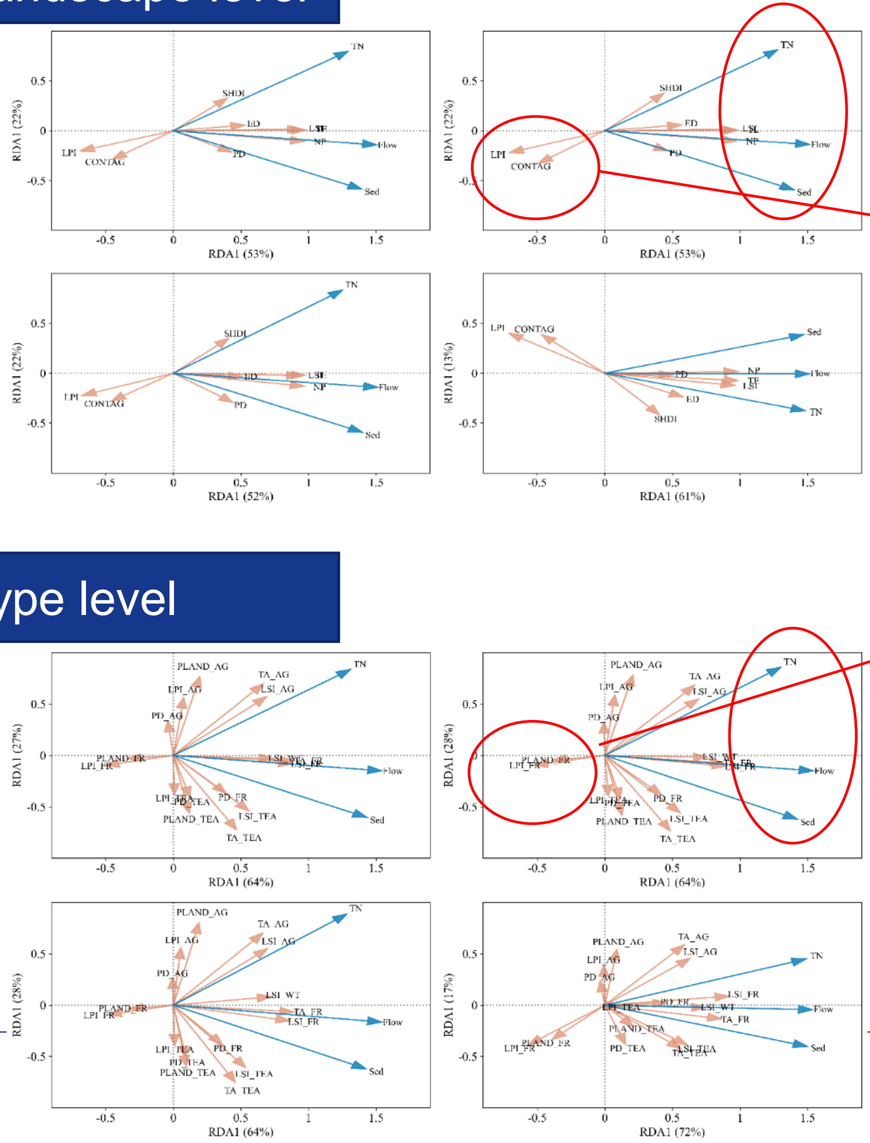
multi-objective optimization algorithm
- NSGA2
- NSGA3
- Genetic Algorithm
- RVEA
- 。。。

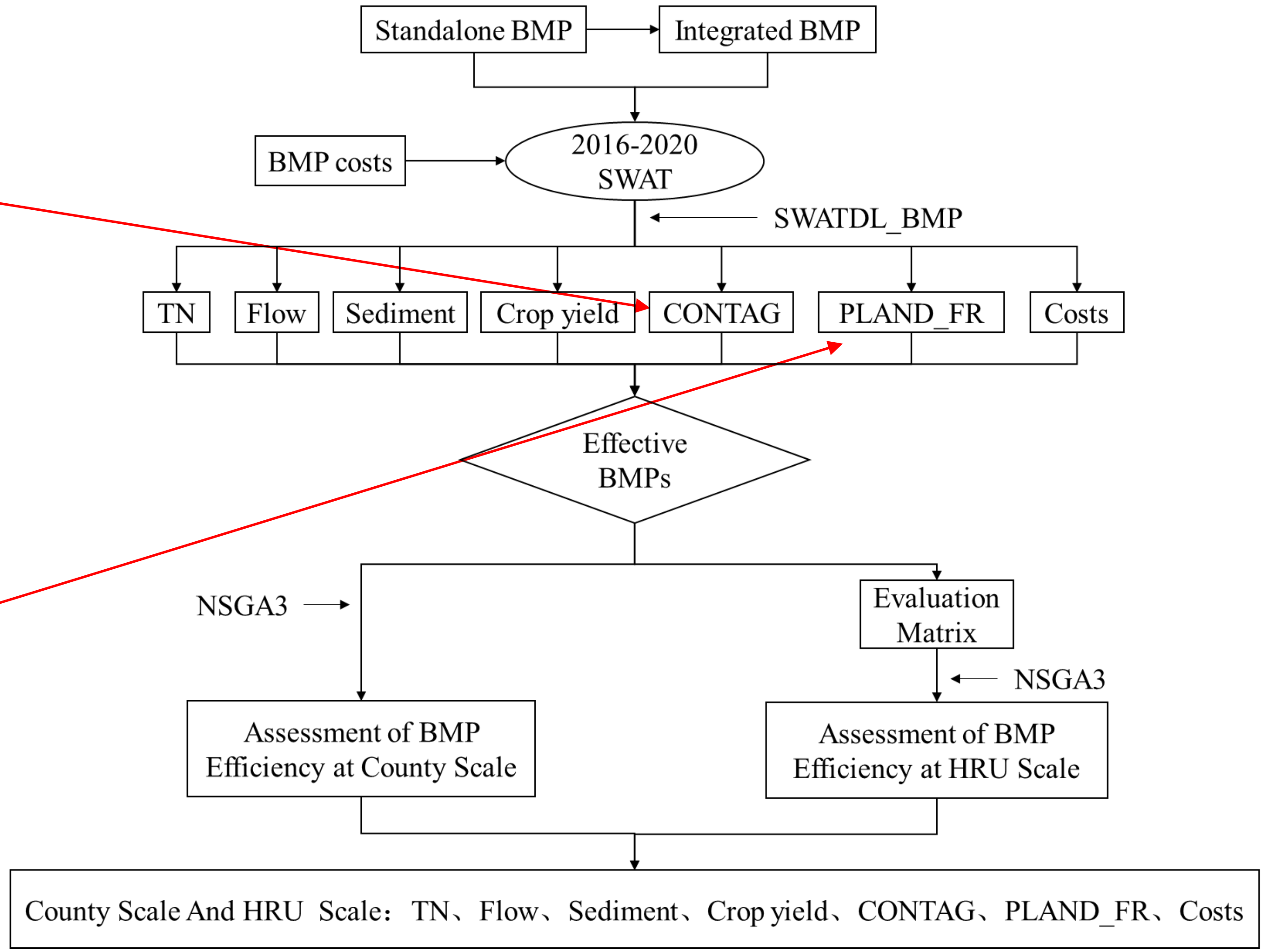
Achieving a trade-off between the objectives of BMPs.

Results: BMP selection

Landscape level

Type level



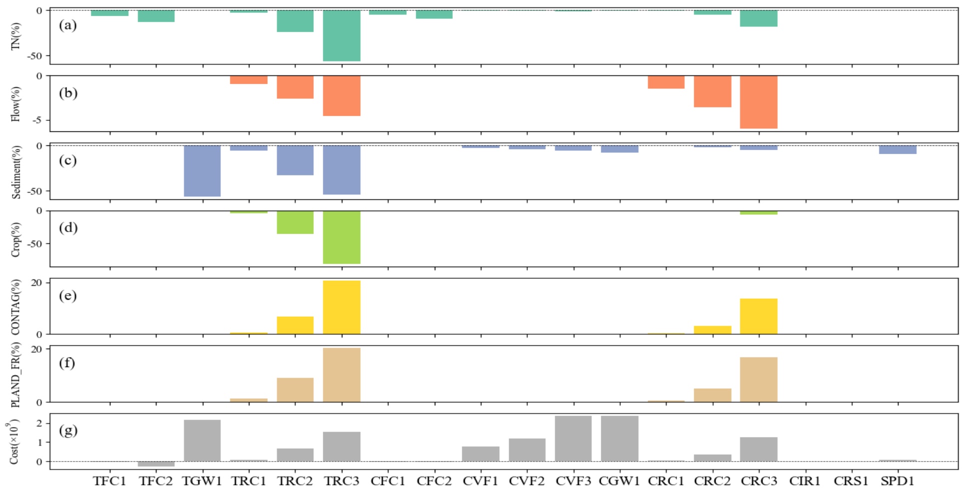


We select several BMPs that are most efficient for different objectives.

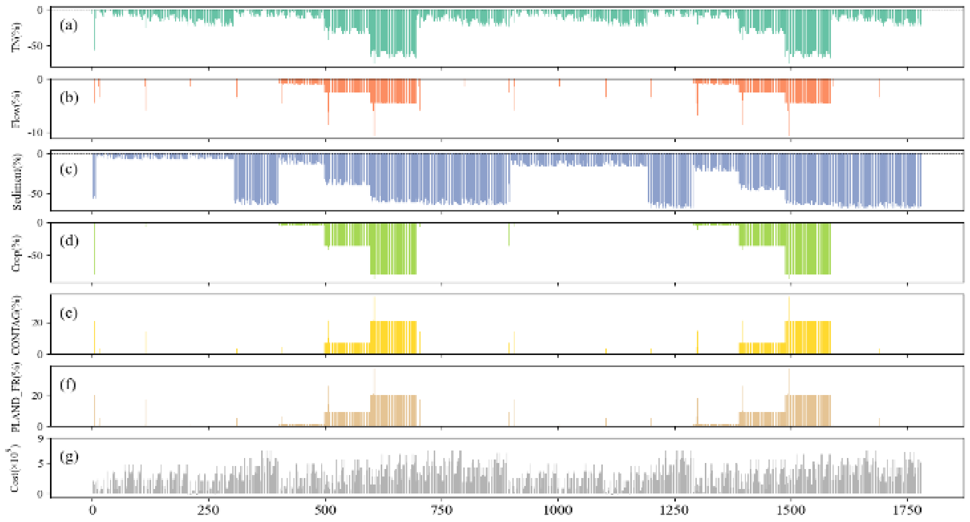
Results: BMP efficiency assessment

Watershed scale

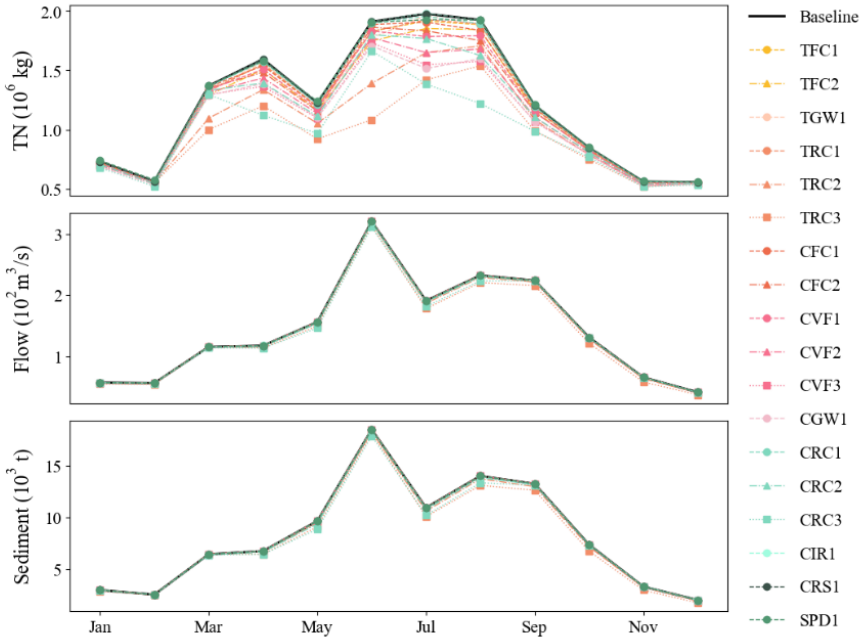
Independent BMP



Integrated BMP

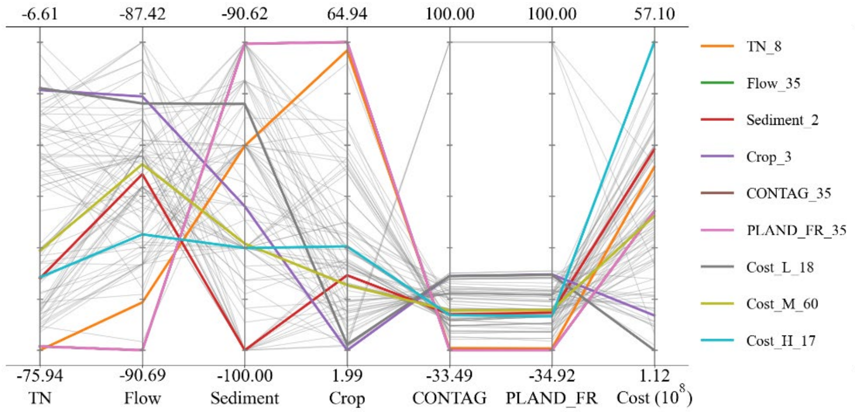


- Independent BMPs: reforestation, fertilizer management have the highest TN reduction rates.
- Integrated BMPs are better than independent BMPs, but integrated BMPs incur higher costs.
- rainy season > dry season.
- 242 types of BMPs



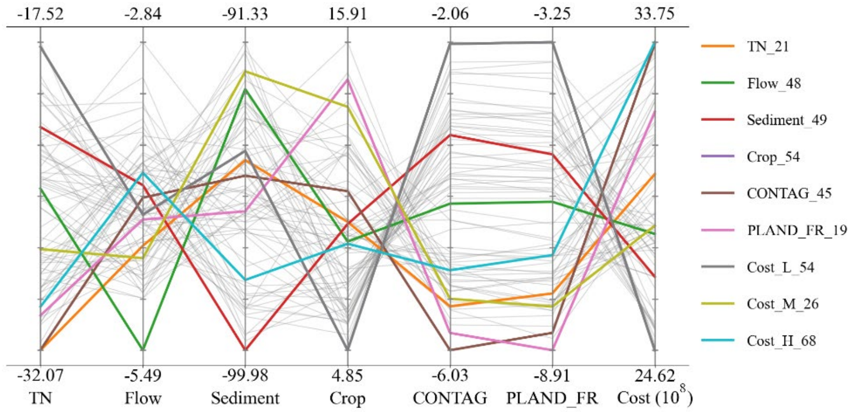
Results: BMP efficiency assessment

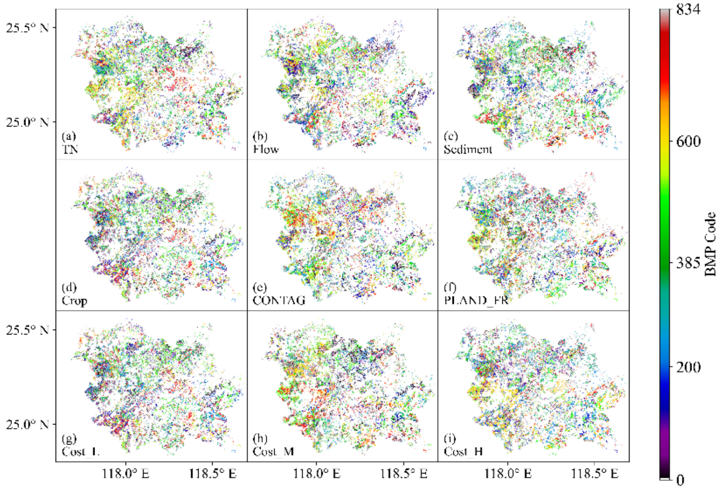
County Scale



Objectives	Anxi Code	Anxi BMP	Yongchun Code	Yongchun BMP	Nanan Code	Nanan BMP
TN	638	TRC3_CFC2_CVF3_CGW1	606	TRC3_CRC3	606	TRC3_CRC3
Flow	605	TRC3_CRC2	606	TRC3_CRC3	606	TRC3_CRC3
Sediment	603	TRC3_CGW1	505	TRC2_CGW1	616	TRC3_CFC2_CGW1
Crop	224	TFC2_CFC2_CGW1	503	TRC2_CVF2	6	TRC3
CONTAG	605	TRC3_CRC2	606	TRC3_CRC3	606	TRC3_CRC3
PLAND_FR	605	TRC3_CRC2	606	TRC3_CRC3	606	TRC3_CRC3
Cost_L	221	TFC2_CFC2_CVF2	506	TRC2_CRC1	506	TRC2_CRC1
Cost_M	615	TRC3_CFC1_CGW1	413	TRC1_CFC1_CVF1	601	TRC3_CVF2
Cost_H	606	TRC3_CRC3	819	TFC2_TGW1_CVF3_CGW1	635	TRC3_CFC1_CVF3_CGW1

HRU Scale

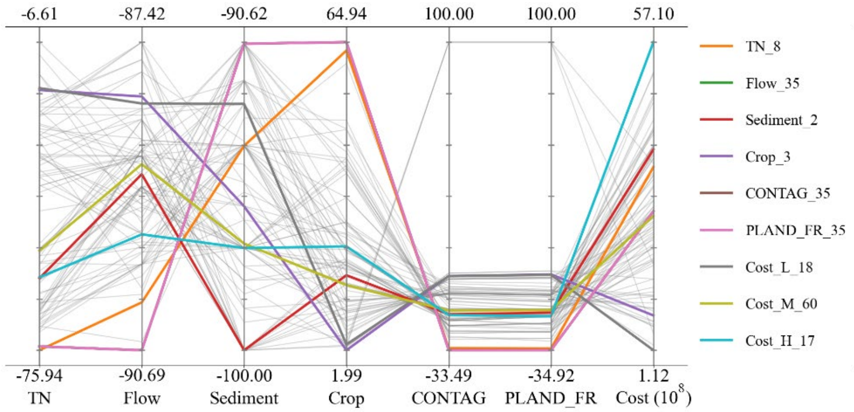




- Significant differences：
  - TN：
    - County (−75.94 ~−6.61 %)
    - HRU (−32.07~ −17.52 %)
  - Cost:
    - County (11 ~571 million ￥)
    - HRU (245 ~ 337 million ￥)
  - Crop:
    - County (−64.94~ −1.99%)
    - HRU (−15.91~ −4.85%)

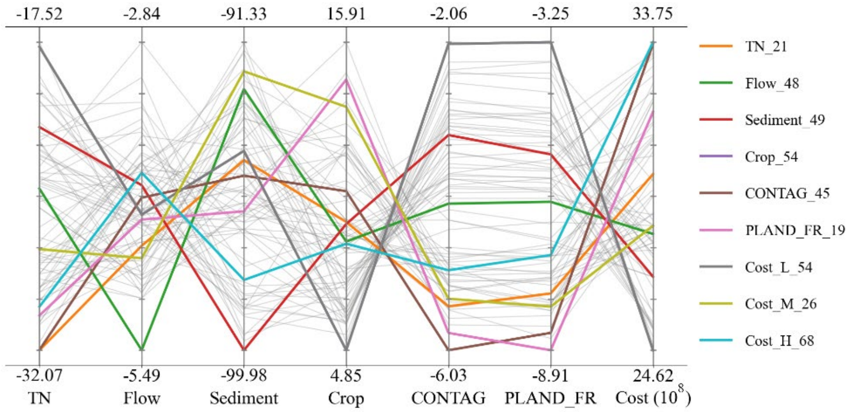
Results: BMP efficiency assessment

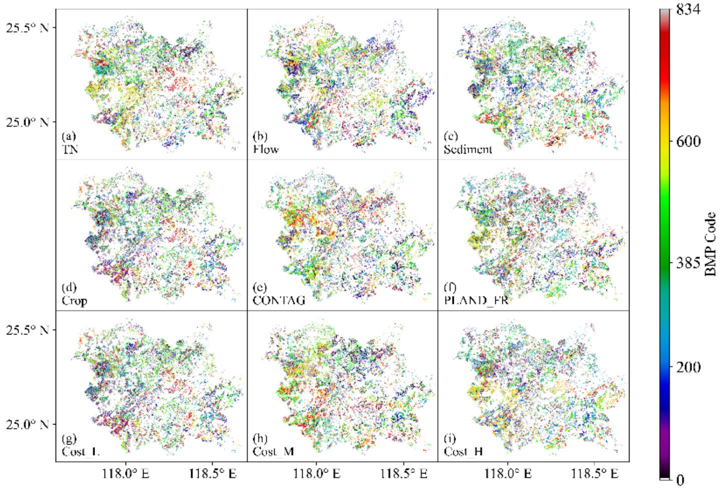
County Scale



方案	安溪县		永春县		下游	
	Code	BMP	Code	BMP	Code	BMP
TN	638	TRC3_CFC2_CVF3_CGW1	606	TRC3_CRC3	606	TRC3_CRC3
Flow	605	TRC3_CRC2	606	TRC3_CRC3	606	TRC3_CRC3
Sediment	603	TRC3_CGW1	505	TRC2_CGW1	616	TRC3_CFC2_CGW1
Crop	224	TFC2_CFC2_CGW1	503	TRC2_CVF2	6	TRC3
CONTAG	605	TRC3_CRC2	606	TRC3_CRC3	606	TRC3_CRC3
PLAND_FR	605	TRC3_CRC2	606	TRC3_CRC3	606	TRC3_CRC3
Cost_L	221	TFC2_CFC2_CVF2	506	TRC2_CRC1	506	TRC2_CRC1
Cost_M	615	TRC3_CFC1_CGW1	413	TRC1_CFC1_CVF1	601	TRC3_CVF2
Cost_H	606	TRC3_CRC3	819	TFC2_TGW1_CVF3_CGW1	635	TRC3_CFC1_CVF3_CGW1

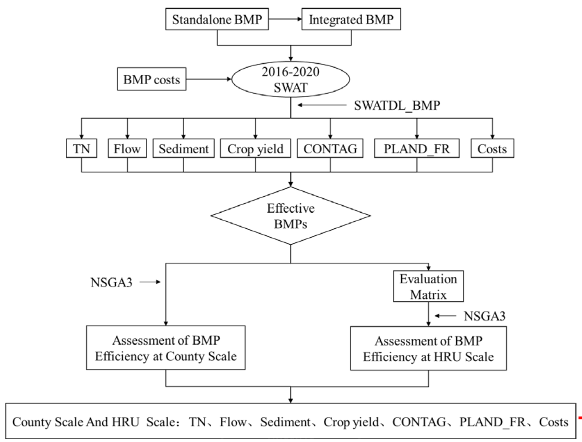
HRU Scale

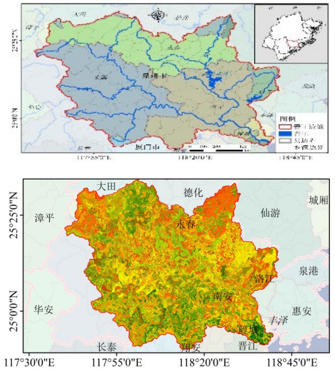


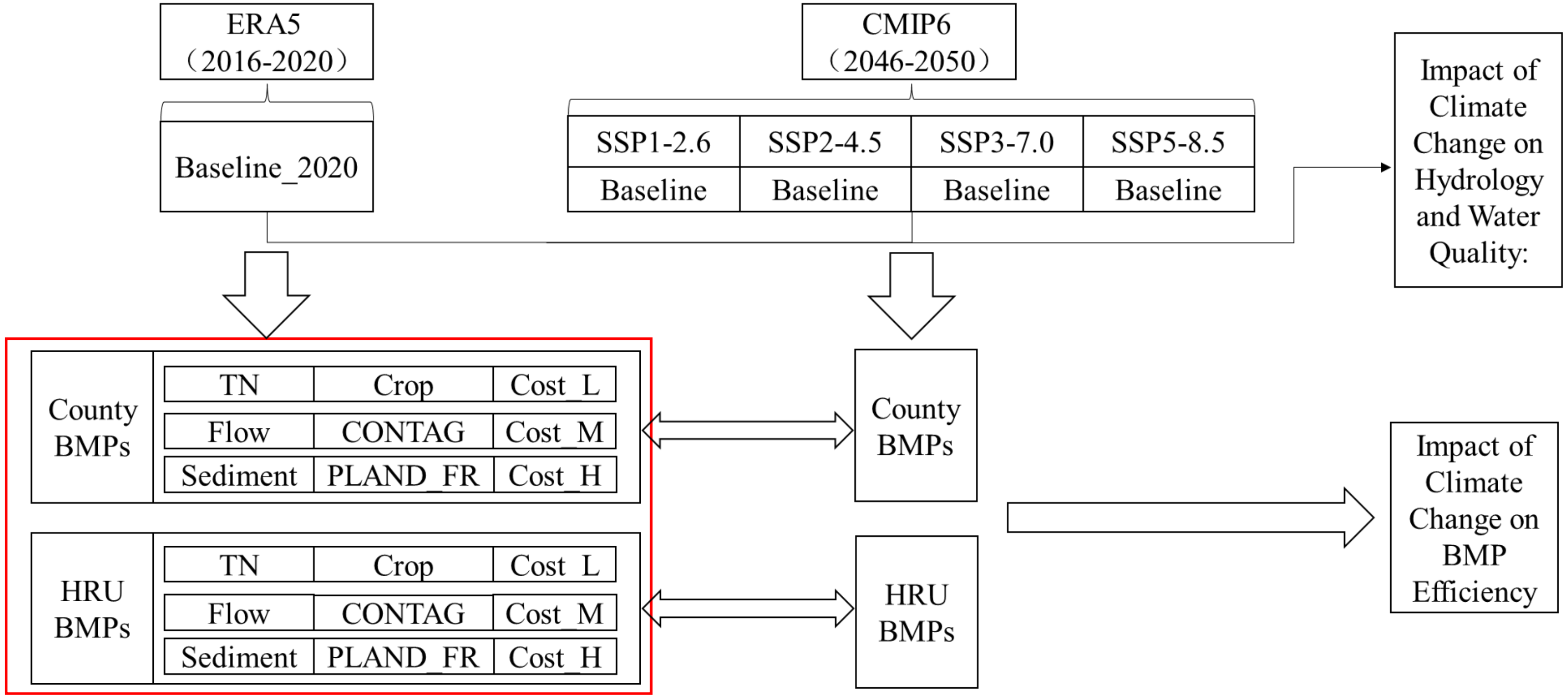


- From the optimization results at both the county scale and HRU scale, select the optimal schemes that are most efficient for the 7 indicators. Then, based on cost, choose three optimization schemes categorized as low, medium, and high expenditure.

PART2



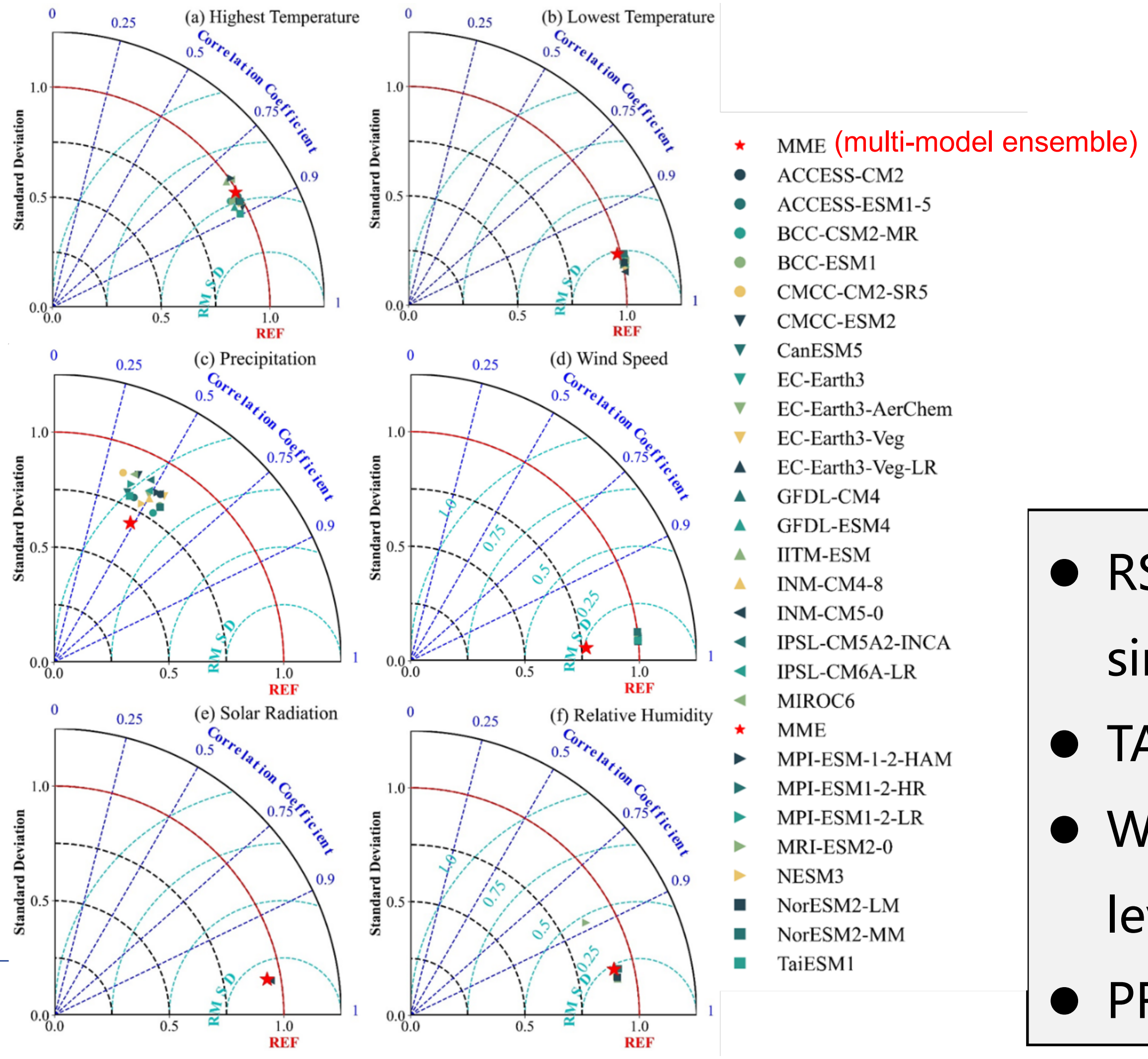


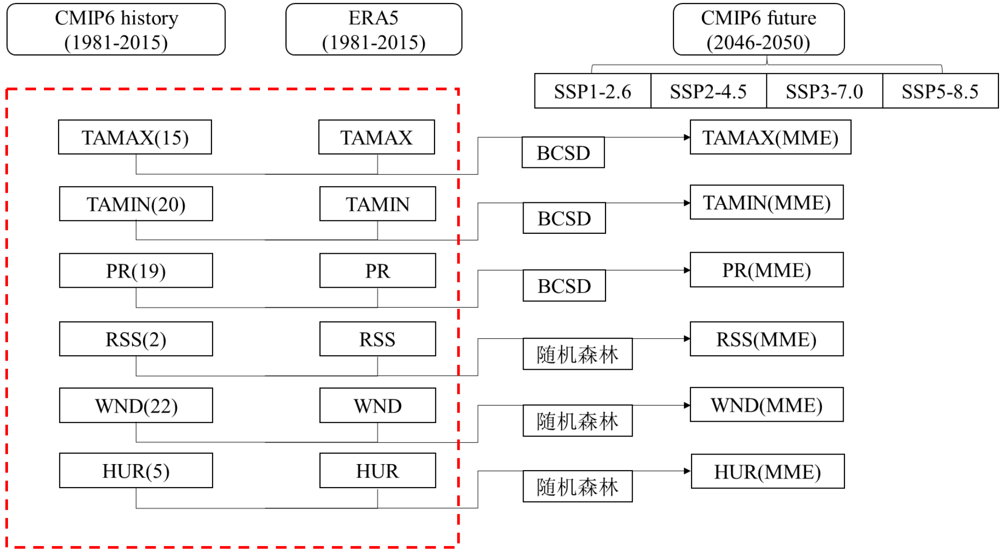


Relationship Diagram Between Future Models and Historical Models

Results: CMIP6 Database

Data Calibration

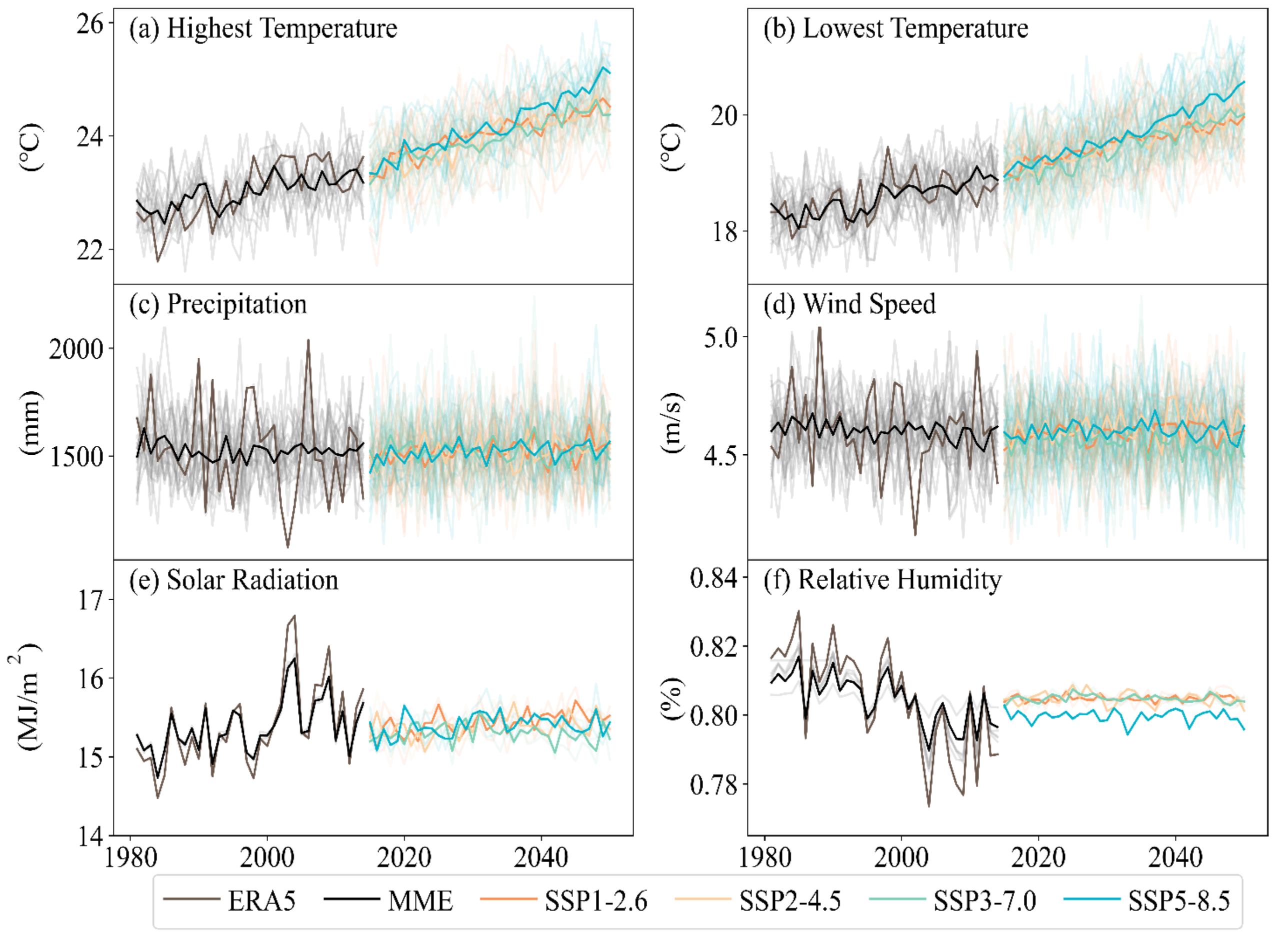


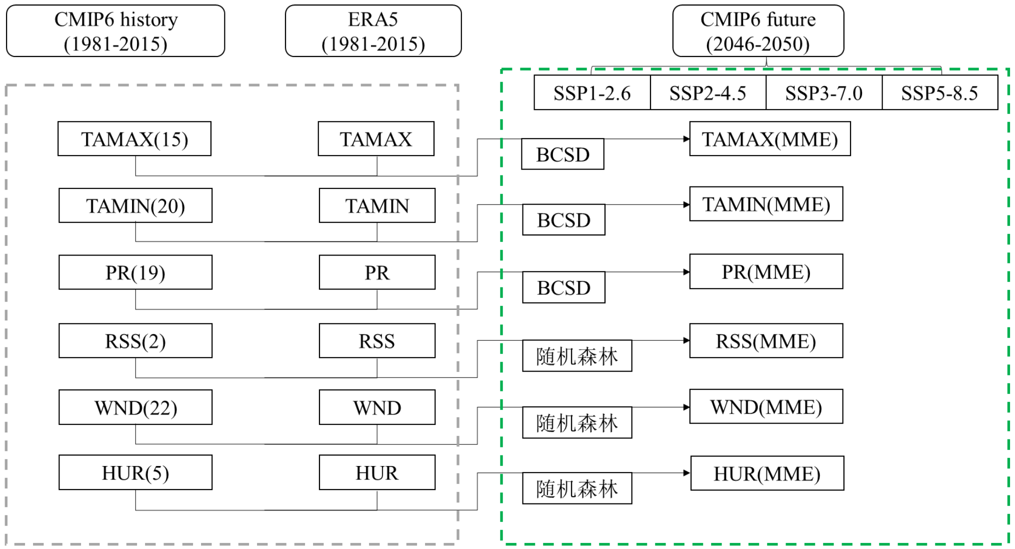


- RSS (2) and HUR (5), high performance, number of simulation mechanisms, uncertainty
- TAMIN and TAMAX, high performance
- WND, relatively high performance, low discretization level
- PR, relatively low performance

Results

Future climate change

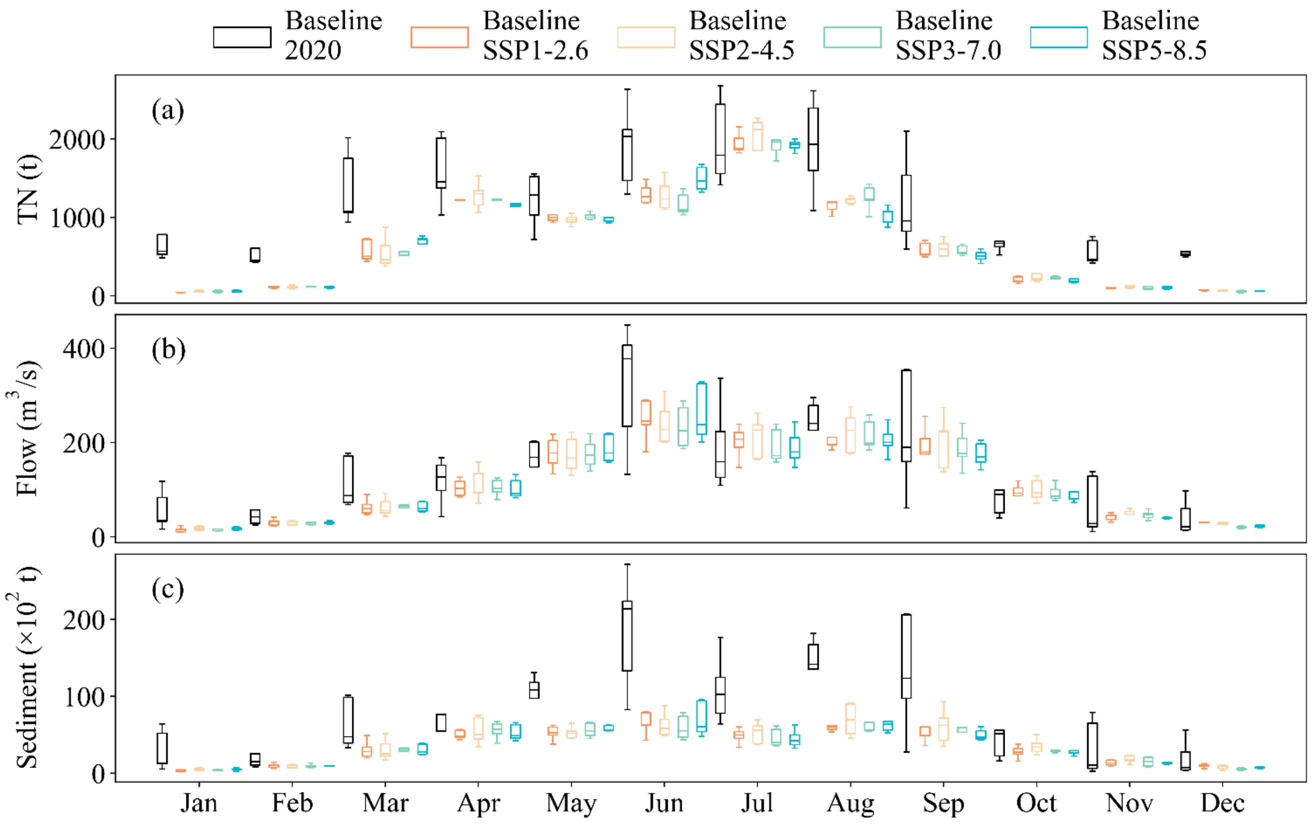




- TAMIN and TAMAX, upward trend; trends in other factors are not significant.
- MME, discretization level lower than historical.

Results

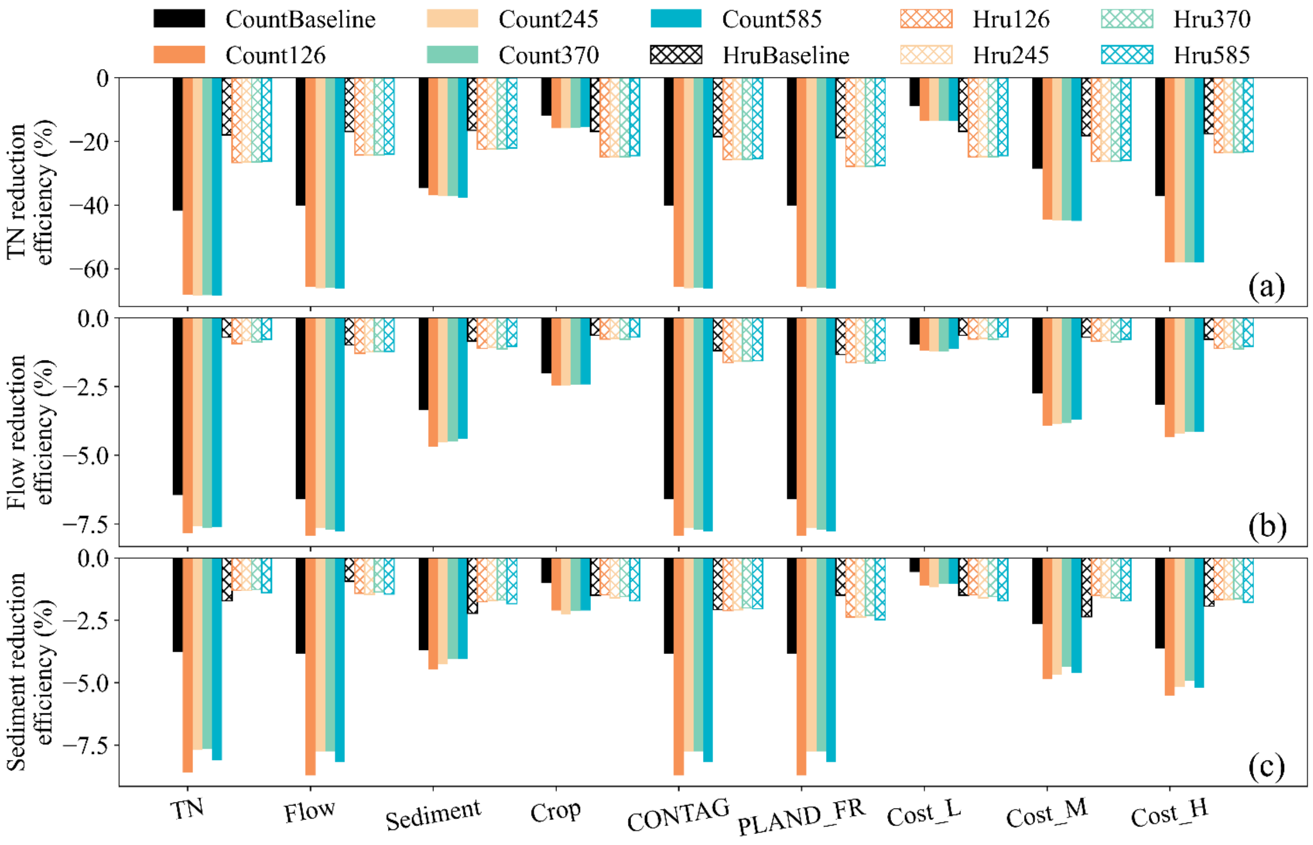
Impacts of Climate Change on Hydrology and Water Quality



- TN, runoff, and sediment all exhibit bimodal distributions throughout the year.
- Runoff, TN load, and sediment load are significantly lower than historical period.
- Runoff and TN decrease more in the dry season, while sediment reduces more in the wet season.

Results

Impacts of Climate Change on Watershed Management Practices



- Future climate change improve the efficiency of BMP reductions.
- County scale > HRU scale.
- No significant differences among SSPs scenarios.

Conclusion

- Do optimal watershed management measures have the same configuration at different spatial scales of management?

➢ There are significant differences in optimal watershed management plans when different spatial scales are chosen. Watershed managers need to select suitable watershed management plans based on management objectives while balancing other management goals within the watershed.

- Does climate change affect the implementation efficiency of optimal watershed management measures? Is there a management measure that can mitigate the effects of climate change?

➢ Climate change does have some impact on future hydrological and water quality changes in the Jinjiang Basin, but this impact is positive. Furthermore, any current management approach will produce greater benefits in the future.

Thank you

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