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International Water Resources Association (IWRA)

Development of multidimensional water poverty in the Yangtze River Economic Belt, China

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XVIII
WORLD WATER CONGRESS
Water for All
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第18届
世界水资源大会
水与万物:
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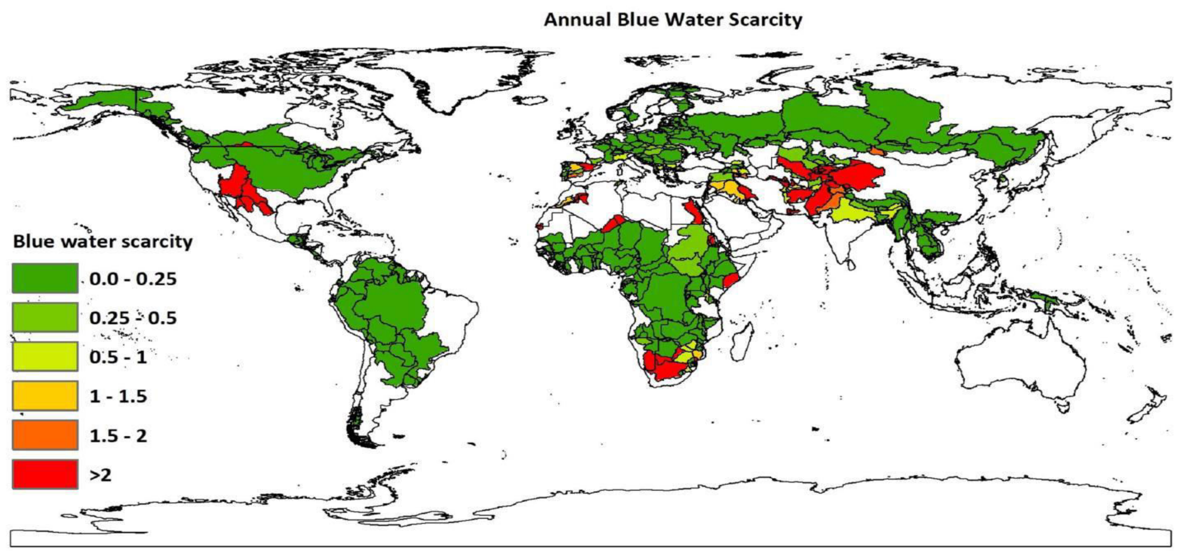
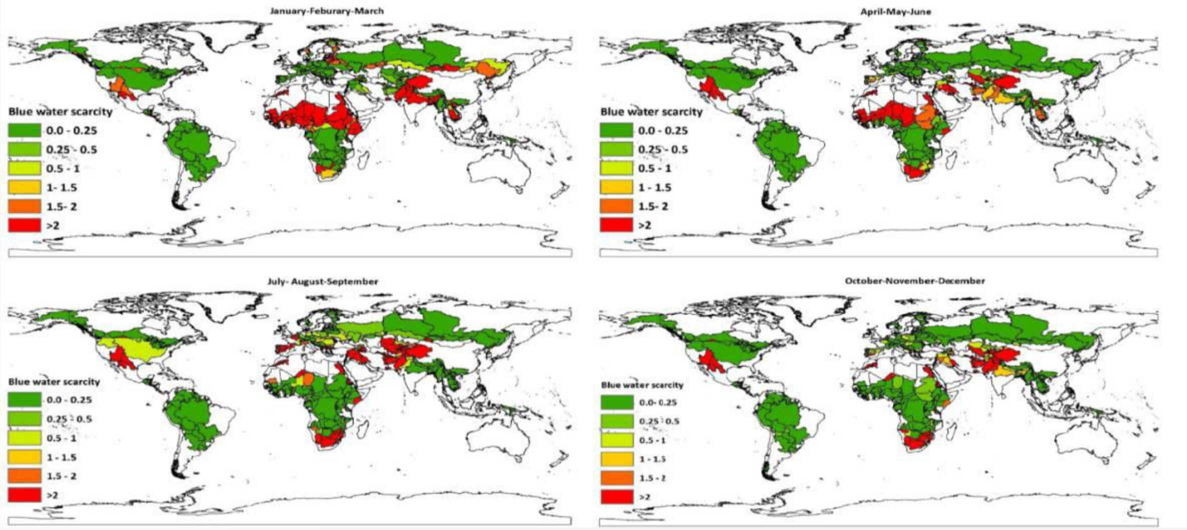
Part I

The state of global water poverty

The world's water supply challenges



Global Transboundary River Basin Water Shortage Degree



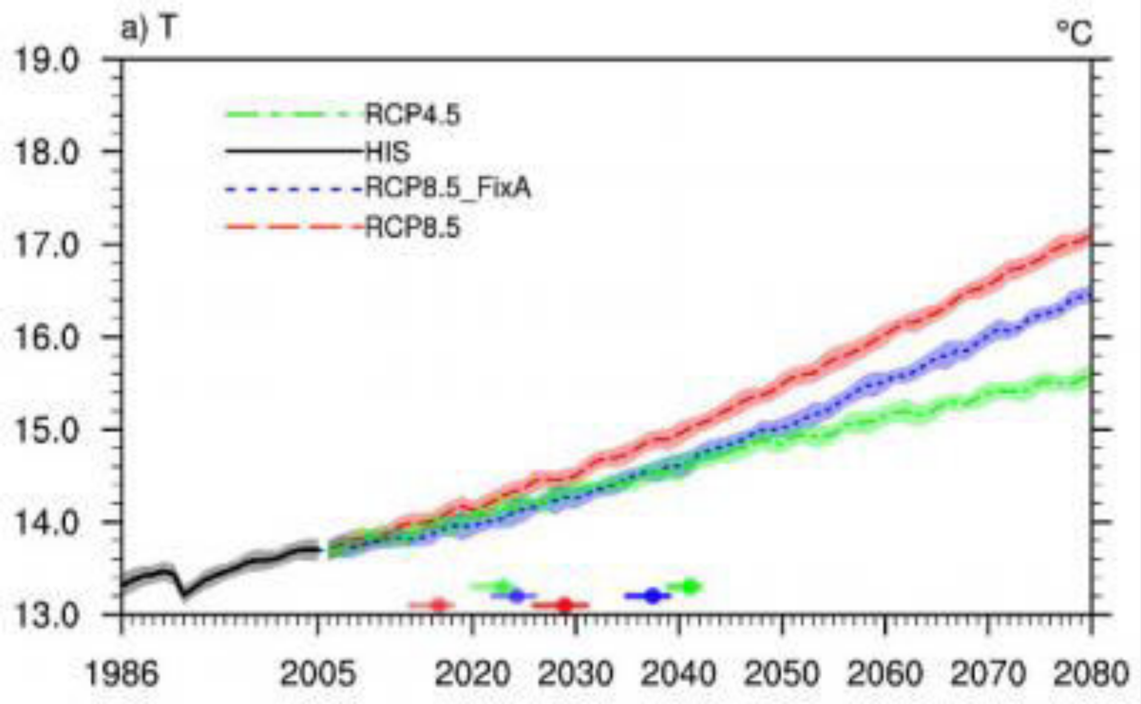
Seasonal shortage of water resources in the transboundary river basin

- ✓ Water resources are **unevenly distributed in time and space** across the world, which has caused an increase in water scarcity of various degrees in many countries and regions, especially in the arid regions of developing countries.
- ✓ Due to population growth, industrialization and urbanization, **water pollution** has become more serious.

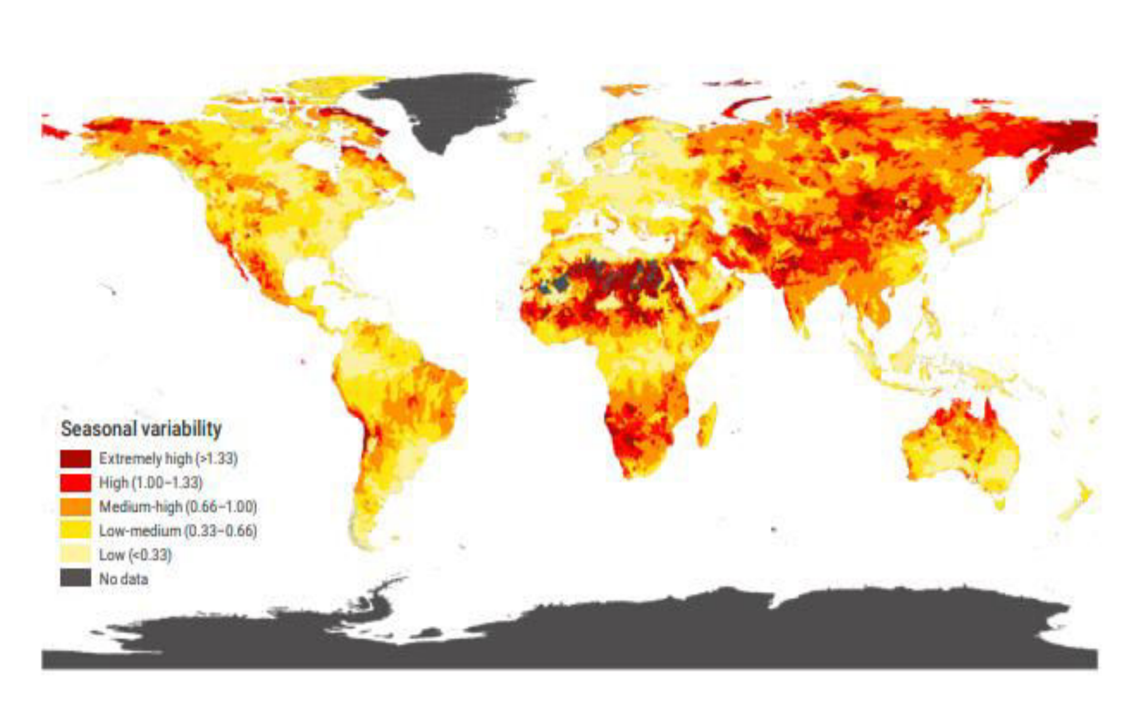
Global water supply faces enormous challenges.

(The United Nations World Water Development Report 2023)

The world's water supply challenges



Global annual mean surface air temperature



Seasonal variability in water availability

Climate change is also impacting **the quantity and quality of water** resources for drinking water supplies, while extreme events can lead to infrastructure and service disruptions.

(Flörke, M et al, Nature Sustainability, 2018； Wang, Z et al, Scientific Reports, 2017)

The evolution of water poverty

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The term poverty is generally used to describe a condition in which low personal income fails to meet one's basic living needs and those of one's family.

Gradually, it has also been extended to the field of natural elements and applied to explain the theory of resource poverty.

Currently, climate change and water pollution have led to serious water shortages around the world. An increasing number of researchers now use the concept of water poverty to research water resources problems.

- Researchers only considered the ability of a region to withdraw water.
- The researchers started considering economic attributes, such as household income in the definition of water poverty.
- Researchers incorporate social property into the concept of water poverty.

- The current assessment framework of the WPI does not comprehensively consider issues, such as water management, water technology, and water welfare.
- Existing research based on the Water Poverty Index (WPI) focuses on traditional water-scarce areas, ignoring that water poverty is not limited to traditional water-scarce areas.
- The existing measurement of water poverty adopts a fixed-weight method, ignoring that the importance of each indicator changes over time.

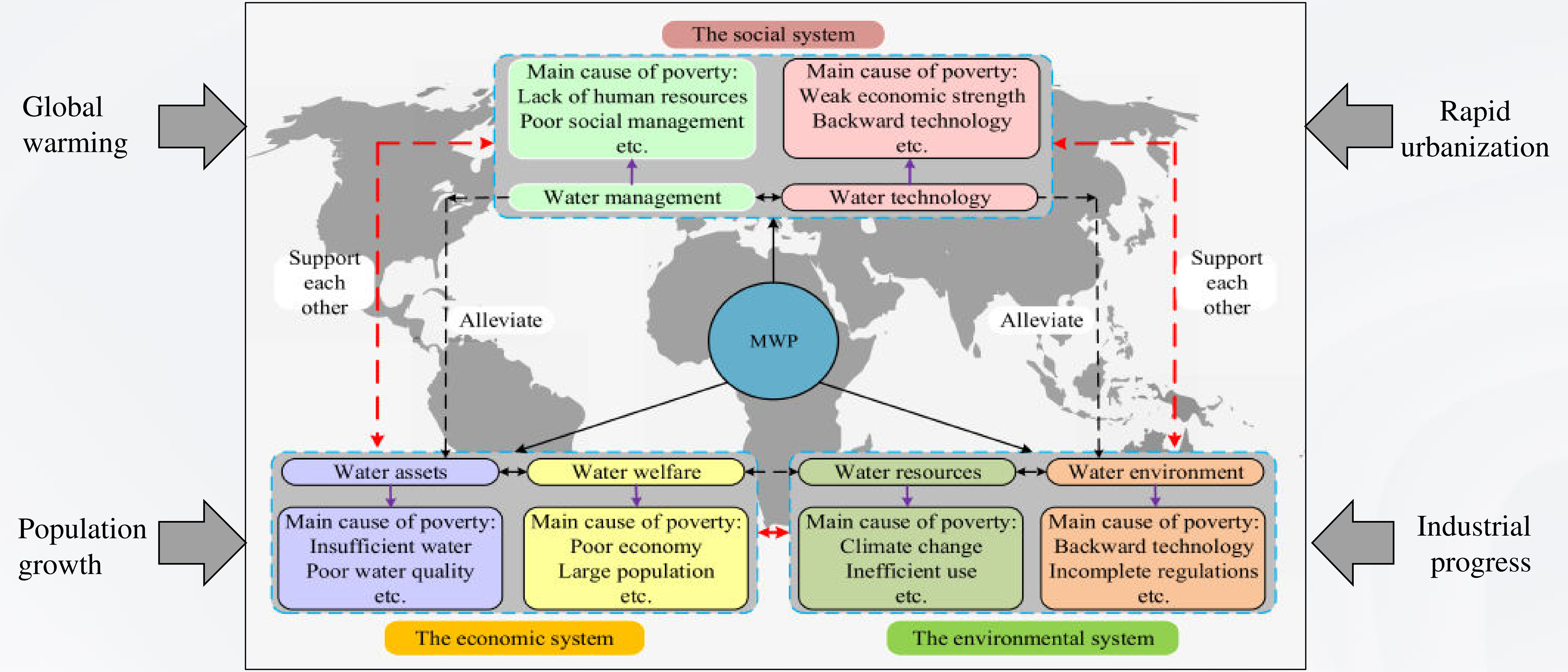
How to assess the impact of water scarcity on the global society, economy and environment from different dimensions is the primary task to solve the global water planning problem.

Part II

Framework of MWP

(MWP, Multidimensional Water Poverty)

Framework of MWP



MWP will continue to evolve with the transfer of information, the exchange of matter, and the flow of energy between different systems.

Description of dimension indices of MWP

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Water Management

WMDI measures the degree of imbalance in the coordination between water resources and the social, economic and ecological systems (Yuan et al., 2019).

Water Assets

WADI measures the stock of water assets and thoroughly considers quantity, quality, and utilization efficiency (Lall and Lin, 1991; Liu and Zou, 2014).

Water Resources

WRDI measures the endowment of water resources and the ability of water to cycle supply (Madani et al., 2014; Zhang et al., 2021b).

Water Technology

WTDI assesses the development level of related technologies for improving the water use and wastewater treatment efficiency (Wilhite and Pulwarty, 2017).

Water Welfare

WWDI assesses the availability of piped water, water intake and drainage facilities, agricultural water facilities, etc. (Bradford et al., 2016).

Water Environment

WEDI assesses the ecological conservation capacity of the water environment affected by human activities (Yuan et al., 2021, 2022b).

The indicators included in each dimension of MWP

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- Based on references, the indicators included in each dimension were selected, and each indicator was **comprehensive and representative**.

MWP evaluation index system

Dimension	Indicator	Unit	Attribute
Water management (M)	Investment in urban environmental infrastructure construction (M1)	Billion yuan	+
	Industrial wastewater treatment investment (M2)	Billion yuan	+
	R&D expenditure as a percentage of GDP (M3)	%	+
	Number of college students per 10,000 people (M4)	person	+
Water technology (T)	Water consumption per 10,000 yuan of GDP (T1)	m^3	-
	Water consumption per 10,000 yuan of industrial added value (T2)	m^3	-
	The proportion of water-saving irrigation area in cultivable land area (T3)	%	+
	Average water consumption per mu for farmland irrigation (T4)	m^3/per mu	-
	Urban daily wastewater treatment capacity (T5)	m^3/per day	+
Water asset (A)	Water asset value per capita (A1)	yuan/per person	+
	Industrial unit water resource asset value (A2)	yuan/m^3	+
	Agricultural unit water resource asset value (A3)	yuan/m^3	+
	Domestic unit water resource asset value (A4)	yuan/m^3	+
	Ecological unit water resource asset value (A5)	yuan/m^3	+

Dimension	Indicator	Unit	Attribute
Water Resources （R)	Groundwater resources per capita (R1)	m^3/per person	+
	Surface water resources per capita (R2)	m^3/per person	+
	Water production modulus (R3)	10000m^3/km^2	+
	Annual precipitation coefficient of variation (R4)	%	-
Water Welfare (W)	Urban per capita daily domestic water consumption (W1)	liters/per person	+
	Urban drainage pipe length (W2)	km	+
	Daily urban water supply per capita (W3)	m^3/per day	+
	Number of public toilets per 10,000 people (W4)	pc/10000 people	+
	Effective irrigated area as a percentage of cultivable land (W5)	%	+
Water Environment (E)	Green coverage in built-up areas (E1)	%	+
	Sewage treatment rate (E2)	%	+
	The proportion of protected areas in the country (E3)	%	+
	Fertilizer usage per mu (E4)	kg/per mu	-
	Pesticide usage per mu (E5)	Kg/per mu	-

Research method of MWP

Measurement of MWP

BP neural network

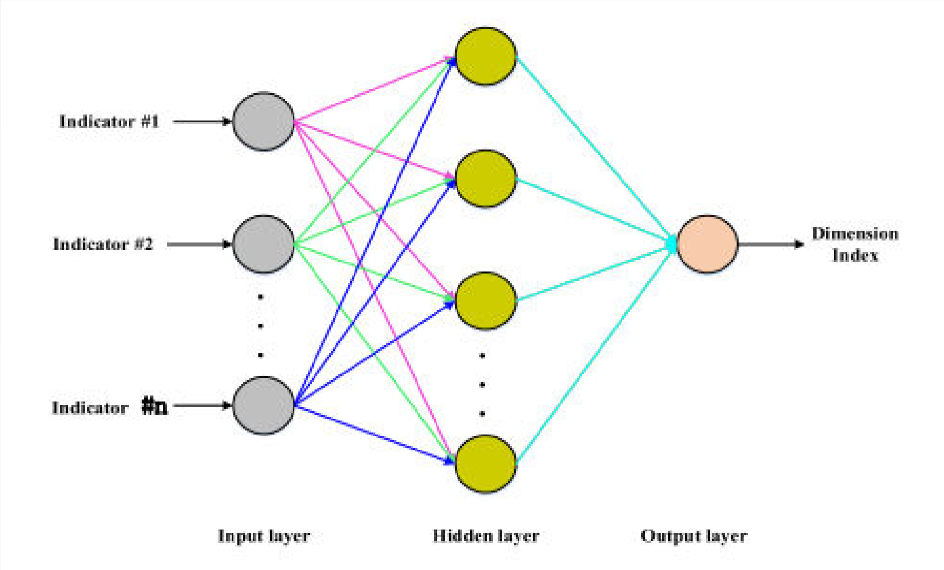


Diagram of BPNN structure

Spatial correlation analysis of MWP

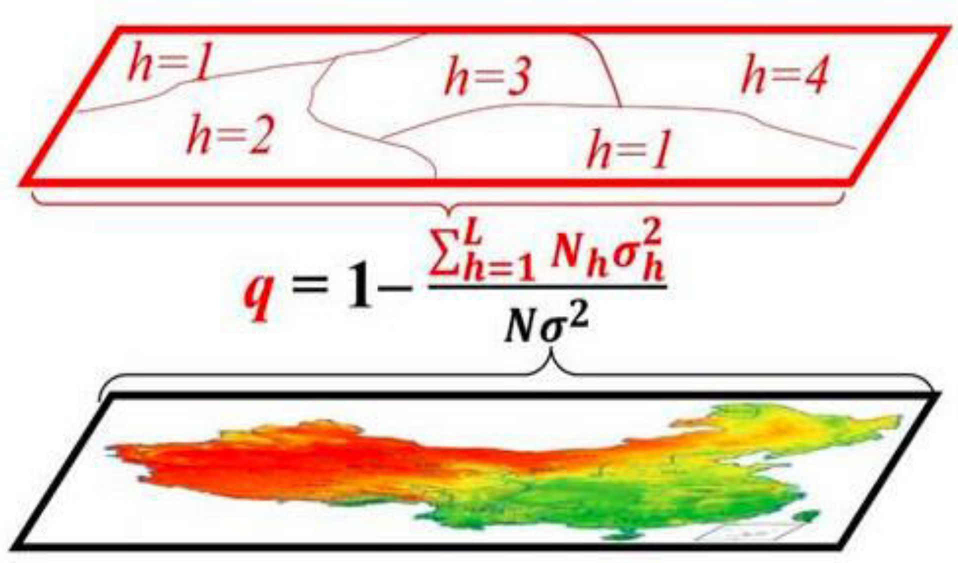
the global Moran's I
the local Moran's I

$$I = \frac{\sum_{i=1}^{n}\sum_{i\neq j}^{n} Z_i Z_j}{S^2 \sum_{i=1}^{n}\sum_{i\neq j}^{n} w_{ij}}$$

$$I_i = \frac{Z_i \sum_{i\neq j}^{n} w_{ij} Z_j}{S^2}$$

Identification of driving factors of MWP

Geodetector



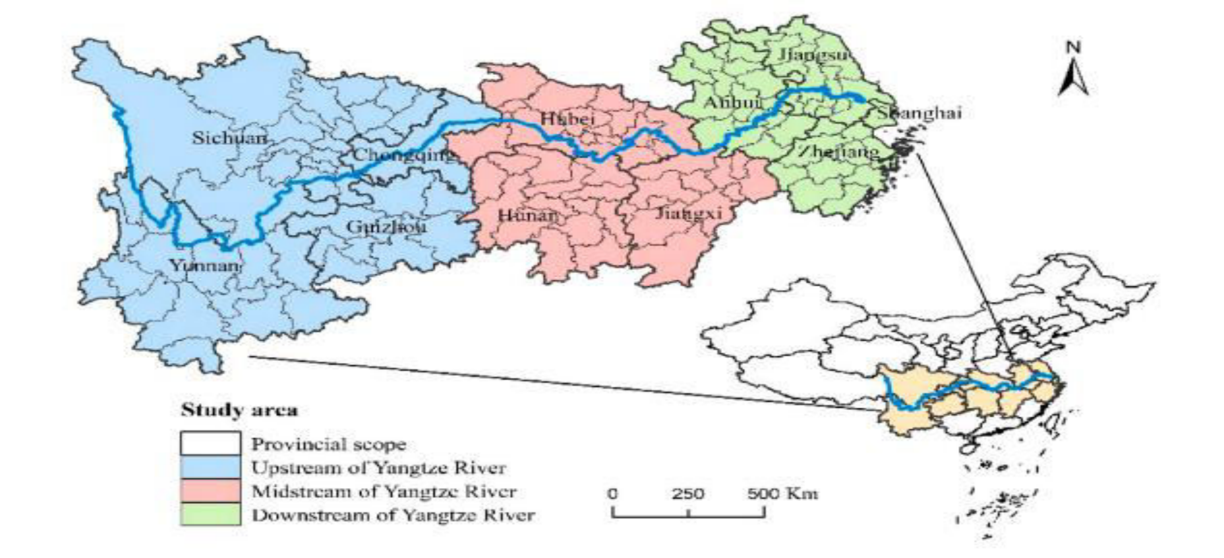
$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2}$$

Principle of Geodetector q-statistic

Part III

The results of MWP in the YREB

The current state of water scarcity in the YREB



Yangtze River Economic Belt, China

The YREB is one of China's important energy and food bases

- The annual **total water consumption** in the YREB was approximately **252.77** billion m^3 from years 2010–2019, and **50%** of this was agricultural water consumption.
- The total discharge of **wastewater** increased from **10.4** billion tons in 2003 to **34.4** billion tons in 2019.

Supporting the sustainable development of society, the economy, and the environment with limited water resources is a rigorous challenge facing the YREB.

Determination of the Network topology of BPNN

Network topology of BPNN each dimension index from 2010 to 2019

Dimension	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
WRDI	4-6-1	4-8-1	4-9-1	4-7-1	4-9-1	4-8-1	4-6-1	4-6-1	4-9-1	4-8-1
WADI	4-8-1	4-9-1	4-8-1	4-6-1	4-8-1	4-9-1	4-6-1	4-8-1	4-8-1	4-6-1
WTDI	4-7-1	4-7-1	4-6-1	4-7-1	4-8-1	4-9-1	4-8-1	4-9-1	4-9-1	4-9-1
WWDI	4-8-1	4-6-1	4-9-1	4-7-1	4-6-1	4-8-1	4-9-1	4-8-1	4-9-1	4-8-1
WEDI	4-9-1	4-7-1	4-9-1	4-8-1	4-6-1	4-8-1	4-9-1	4-9-1	4-9-1	4-7-1
WMDI	4-6-1	4-9-1	4-6-1	4-8-1	4-6-1	4-7-1	4-9-1	4-6-1	4-8-1	4-8-1

1. The **BPNN** was built using **MATLAB** to assess the MWP in the YREB.
2. **Tansig** and **Purelin** are used as the **activation functions of the hidden layer** and **output layer**, respectively.
3. The **number of neurons in the hidden layer** is determined by **repeated experiments** according to the principle that **the least training time is best**.
4. The table above shows the **number of neurons in the input, hidden, and output layers** of each trained network.

Evaluation of MWP in the YREB

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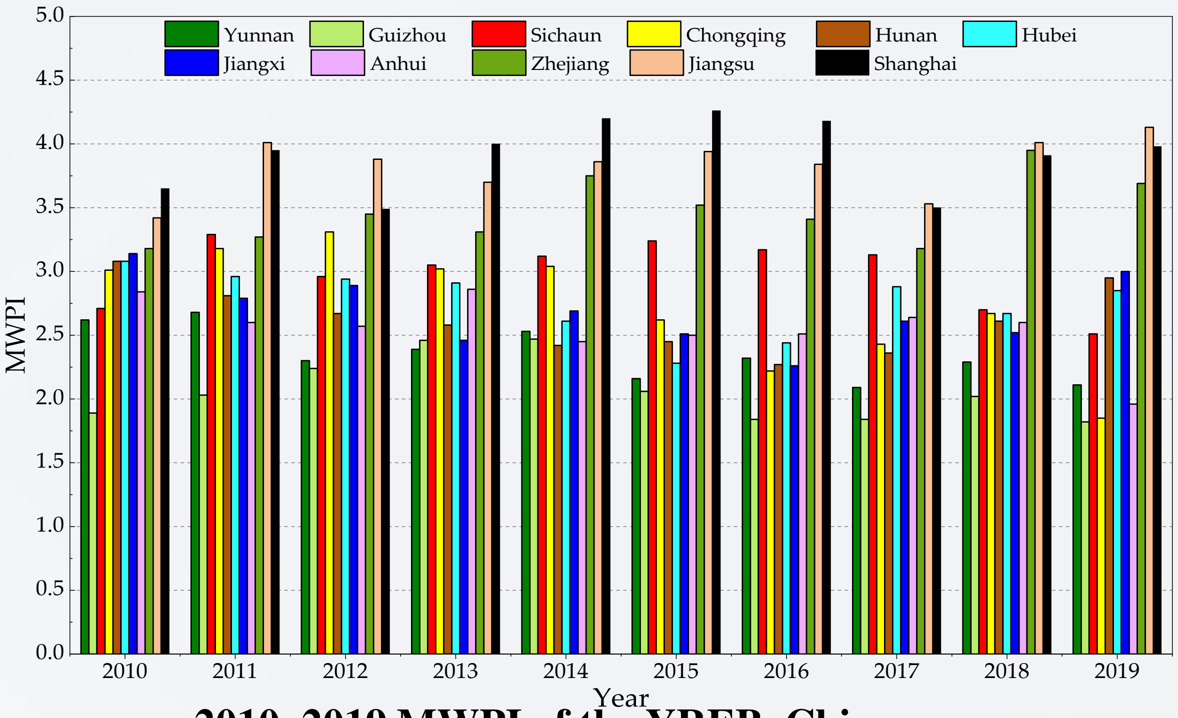
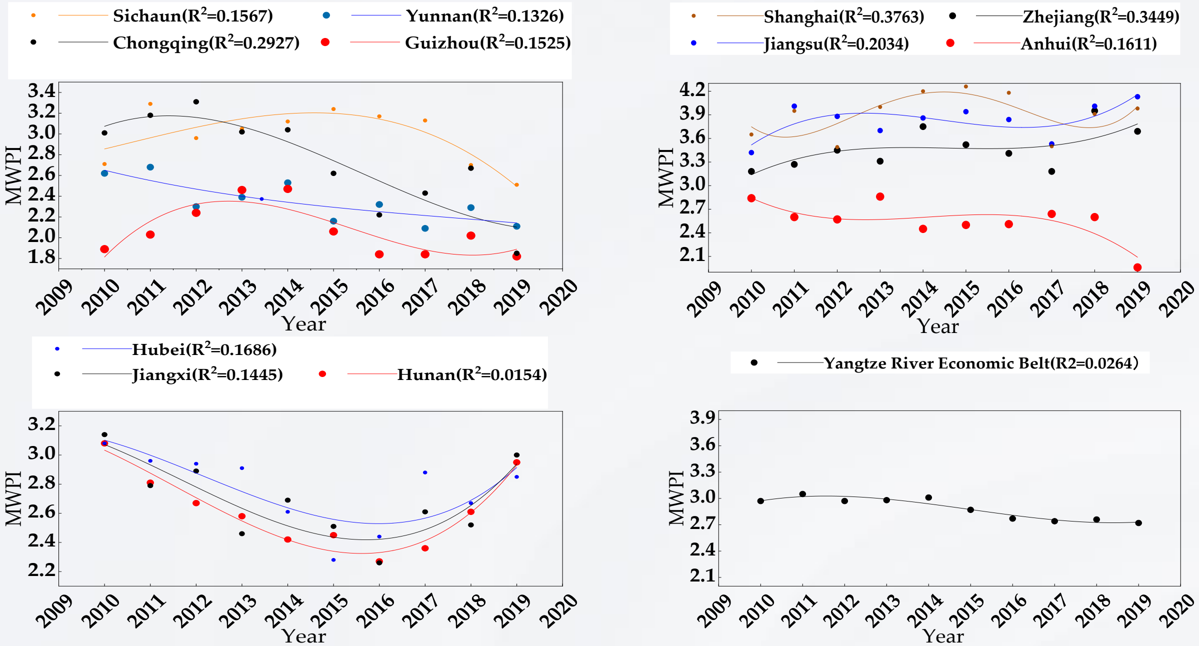


2010–2019 MWPI of the YREB, China



Variation of the average MWPI in the upper, middle, and lower reaches of the YREB

- The MWPI of **Shanghai City, Jiangsu, and Zhejiang Provinces** which are developed economies, remained at **a high level** during the study period.
- The MWPI of provinces with relatively poor economic development, such as **Yunnan, Guizhou, and Anhui Provinces**, was **small** from 2010 to 2019.

- The MWPI of **the upstream provinces** shows an overall **downward trajectory**.
- There is a significant "**V-shaped**" trend in the MWPI among the **midstream provinces**.
- A **fluctuating increasing** trend in MWPI is shown among the **downstream provinces**, with the exception of **Anhui Province**.
- The MWPI of **the YREB** shows a **slow downward** trend.

Analysis of the spatial effects of MWP in the YREB

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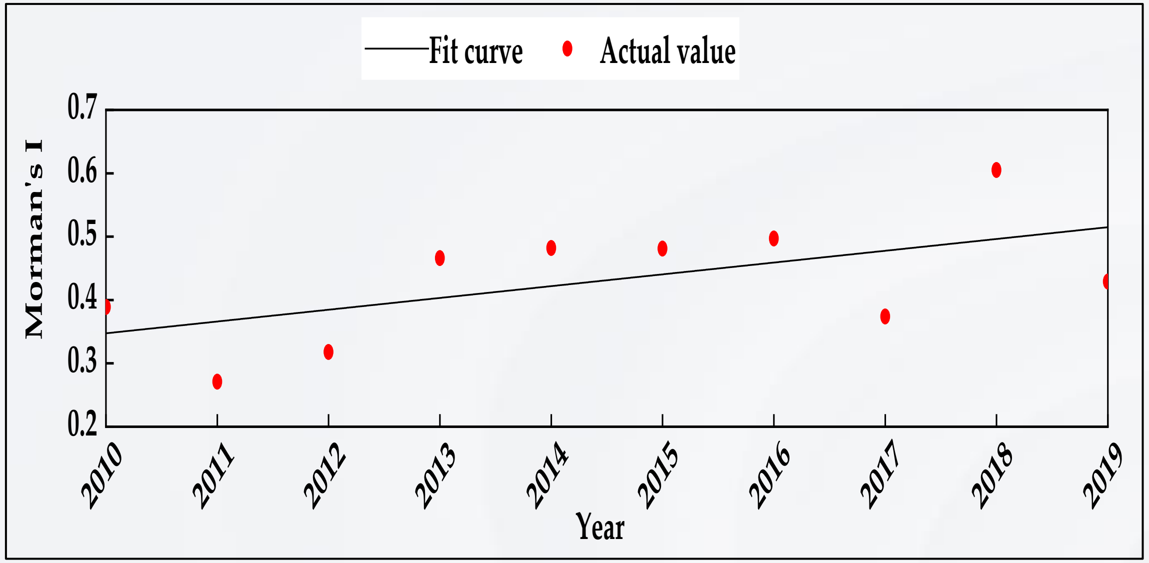
- The table shows that the global Moran's I value is positive and passes the significance test, which indicates that a significant spatial agglomeration effect is clear in the YREB.
- Overall, the global Moran's I value of the MWPI in the YREB is between 0.271 and 0.605.

Global Moran's I

Years	Global Moran's I	Z value	P value
2010	0.389	2.885	0.004***
2011	0.271	1.957	0.050**
2012	0.318	2.118	0.034**
2013	0.466	2.953	0.003***
2014	0.482	2.953	0.003***
2015	0.481	2.959	0.003***
2016	0.497	3.050	0.002***
2017	0.374	2.383	0.017**
2018	0.605	3.567	0.000***
2019	0.429	2.629	0.009***

Note: *, ** and *** represent significant at the 10%, 5%, and 1% significance levels, respectively.



Simulated verses actual global Moran's I value of the MWPI

- A growing trend with small fluctuations is shown in the chart above. This shows that the YREB's MWP is spatially dependent and that the degree of dependence increases yearly.

Analysis of the spatial effects of MWP in the YREB

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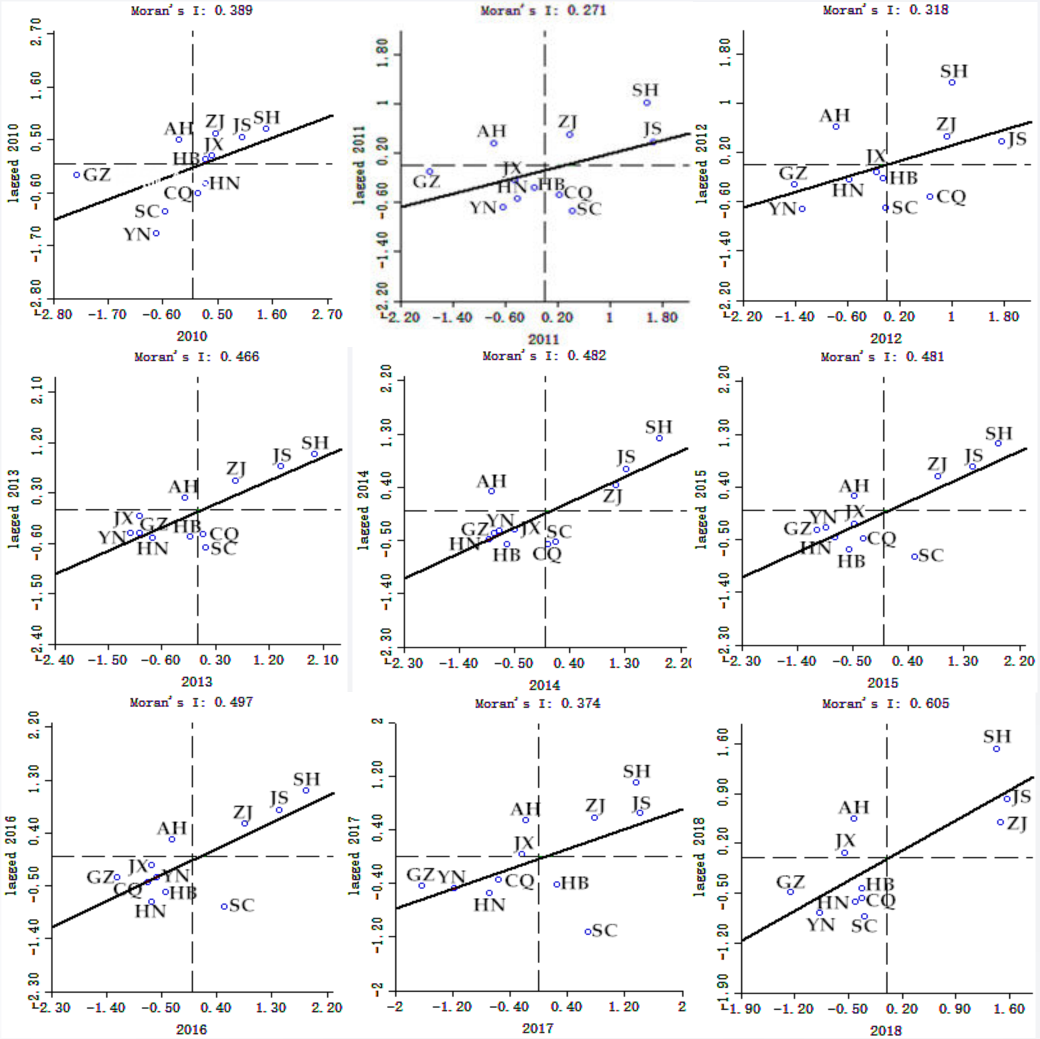
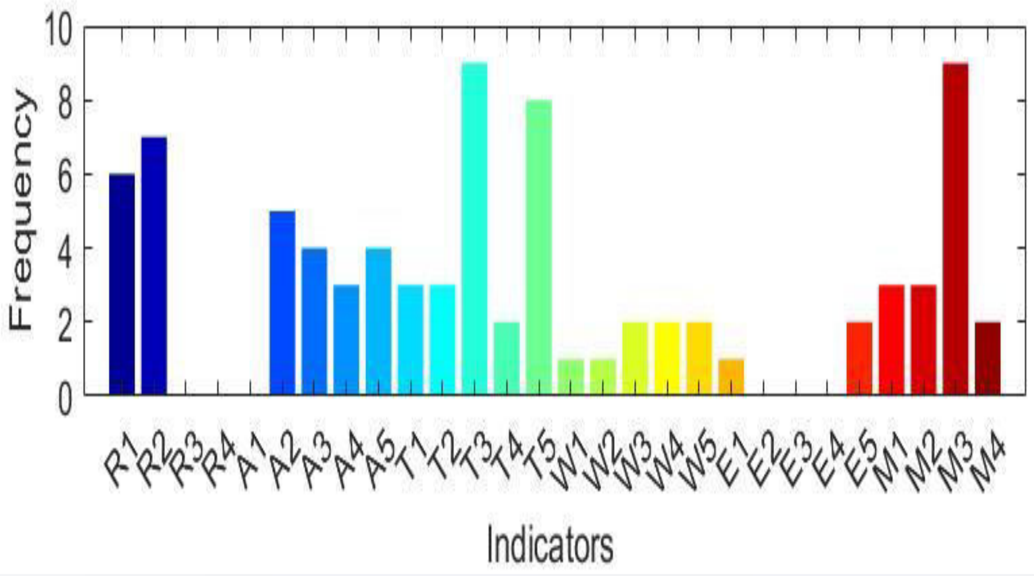
Moran's scatter plot of MDWPI in the YREB



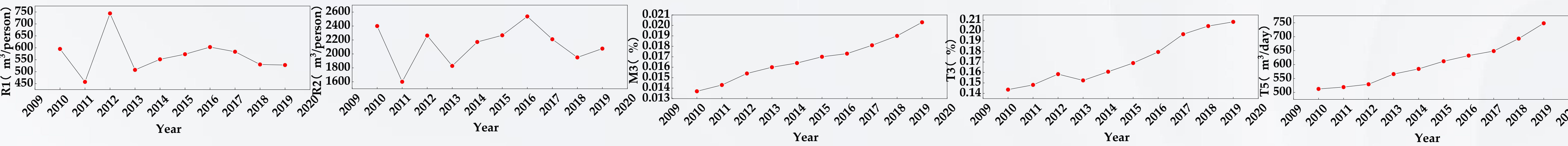
- **Shanghai City, Jiangsu, and Zhejiang** Provinces are always observed in the **H-H quadrant**.
- **Anhui** Province appeared in the **L-H quadrant** for the study period.
- **Yunnan and Guizhou** Provinces are always in the **L-L** quadrant, while **Chongqing City, Sichuan** Province, and the midstream provinces of the YREB, move back and forth between the **L-L and H-L** quadrants.
- **The provinces in the H-L quadrant frequently changed.**

Identification of driving factors of MWP in the YREB

Frequency chart of the driving factors of MWP



The indicators with a frequency greater than 5 were selected as the main driving factors, including the R&D expenditure as a percentage of GDP (**M3**: 9 times), the proportion of water saving irrigation area in the cultivable land area (**T3**: 9 times), the urban daily wastewater treatment capacity (**T5**: 8 times), the land surface water resources per capita (**R2**: 7 times), and the groundwater resources per capita (**R1**: 6 times).



Changes in the main driving factors of MWP in the YREB

- R1 and R2 show **fluctuating trends**.
- M3, T3 and T5 **increased by 48%, 45%, and 46%**, respectively.

Part IV

Policy recommendations

Policy recommendations

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- The strictest water management system should be implemented.
- **Hunan, Yunnan, and Sichuan Provinces should strengthen the control of agricultural pollution.**
- **The development of clean industries such as ecological resources is strengthened by the upper reaches, particularly Yunnan and Guizhou Provinces.**
- Regarding the middle reaches, water pollution caused by traditional industries is reduced through green production technology.

- **The construction of rural drinking water projects and sanitary toilets must be increased by the government.**
- The government should guide the population in the lower reaches to move in an orderly manner to the middle and upper reaches.
- As per actual location advantages and the relationship between water supply and demand in the YREB, **the upstream regions rationally increase the development of water resources to alleviate MWP in the YREB.**

- When promoting the follow-up development of the YREB, it is necessary to **break down the policy barriers between provinces:** strengthen joint development, and highlight the leading role, so as to realize the integrated development of the YREB.
- **Relying on its local advantages is to develop differentiated industries:** building a regional economic cooperation mechanism is to narrow the upstream-midstream-downstream differences.

Thank you!

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