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Decoupling Analysis of Water Resource Utilization and High-Quality Economic Development in the Wei River Basin, Shaanxi Province

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Abstract: The Wei River Basin occupies a pivotal position in China's northwest region, holding immense strategic importance. Water scarcity has emerged as a critical constraint on local socioeconomic development, necessitating urgent analysis of the decoupling between water resource utilization and high-quality economic growth in the Shaanxi Wei River Basin. This study aims to provide a foundation for efficient water resource management within the basin. Therefore, this study utilizes data from 2000 to 2021 on water resource utilization and urban economic development indicators in the Shaanxi Wei River Basin. First, it conducts a spatiotemporal analysis of water consumption volume, structure, and efficiency in the basin based on the coefficient of variation and the Sierr coefficient. Second, it employs grey correlation analysis to examine the degree of association between water resource utilization types and local high-quality economic development indicators. Finally, the Tapio decoupling index model is applied to evaluate the decoupling between water resource utilization and high-quality economic development in the basin. Findings reveal: (1) Constrained by economic foundations and development conditions, significant spatial disparities exist in water use patterns across cities in the basin, particularly with deepening imbalances in domestic water consumption exhibiting pronounced spatial characteristics; (2) High correlation exists between indicators of high-quality economic development and water use patterns in the basin, with national economic conditions and government fiscal status exhibiting the strongest association with water consumption; (3) Water use and economic development in the basin generally exhibit decoupling, indicating relative coordination but not absolute separation; From an industrial structure perspective, the decoupling elasticity of industry and agriculture outperforms the overall decoupling elasticity, while the latter surpasses that of the service sector. Consequently, the Wei River Basin in Shaanxi must pursue harmonious coexistence between humans and water through optimizing industrial structure, enhancing water resource utilization efficiency, and promoting high-quality development in the tertiary sector.

1. Introduction

In 2019, the CPC Central Committee stated at the symposium on ecological conservation and high-quality development in the Yellow River Basin[1] that the basin is a vital ecological barrier and economic zone, as well as a key poverty-alleviation area in China, pivotal to its socioeconomic development and ecological security. Promoting ecological conservation and high-quality development there has become a major national strategy.

The Wei River Basin in Shaanxi, a crucial part of the Yellow River Basin and a key economic, cultural, and ecological hub in Northwest China, plays a vital role in implementing this strategy through water resource management. As the core of Shaanxi and part of the Guanzhong Plain, it hosts 65% of the province's population and contributes 70% of its GDP, yet holds only about 4% of China's total water resources. With rapid economic growth, the water supply-demand imbalance has worsened, making balancing efficient water use and high-quality development an urgent issue.

Therefore, understanding the relationship between water resources and high-quality economic development in the Wei River Basin of Shaanxi and thoroughly investigating the decoupling relationship between water resource utilization and high-quality economic development there holds significant practical importance for formulating scientific water resource management policies, reducing water consumption intensity, and supporting high-quality economic development in the region.

2. Review of the Current State of Research

2.1 Current Situation Abroad

At the end of the 20th century, the OECD proposed a decoupling index calculation model[2], initially applied to agricultural policy research and later expanded to environmental economics.

Bruyn et al.[3] argued that decoupling means reducing resource consumption or environmental impact while maintaining economic growth, but noted it may not be permanent, suggesting some developed economies might have entered a "re-coupling" phase. They also proposed that the relationship between environmental pressures and welfare may follow an N-shaped rather than an inverted U-shaped trajectory. Tapio[4], studying CO_2 emissions decoupling in Finnish road transport, proposed an elasticity analysis model. Building on Vehmas' six types, he added recession- and expansion-coupling, defined elasticity coefficient ranges, and established an eight-category system to differentiate decoupling levels and patterns.

2.2 Current Situation in China

Many domestic scholars have applied decoupling models to analyze the coordinated relationship between economic development and various factors, revealing underlying patterns[5]. Research on the decoupling relationship between water resource utilization and economic development is also extensive: Yujie Shen[6] analyzed this relationship in Henan Province using a decoupling model, while Hao Zhang et al.[7] conducted a similar study in Guizhou Province. Xifeng Wang et al.[8] explored the decoupling mechanism between water resources and economic growth in Beijing, and Hengquan Zhang et al.[9] examined the relationship between regional economic growth and industrial water consumption in the Yangtze River Delta using decoupling effort models, LMDI, and the Tapio elasticity index. Zhongwen Pan et al.[10] analyzed the decoupling relationship between water resource utilization and economic growth in China from a water footprint perspective. Haozhe Yu et al.[11] used spatial difference and grey correlation methods in the Beijing-Tianjin-Hebei region.

2.3 Methods and Data Sources

2.3.1 Spatial Difference Analysis

(1) Coefficient of Variation

The Coefficient of Variation[12] is a dimensionless statistical measure used to quantify the dispersion of data. It reflects the degree of deviation of a particular indicator from the overall average level. The calculation formula is as follows:

$$v_{i}=\frac{\sigma_i}{\bar{x}_i} \tag{1}$$

Where: vi denotes the coefficient of variation for the i-th indicator; The term σ_i denotes the standard deviation for the i-th indicator. $\bar{x}_i$denotes the mean value for the i-th indicator. A higher value of vi indicates a greater degree of variation among the indicators.

(2) Sierr coefficient

The Sierr coefficient, also known as Sierr entropy[13], Since this index can be decomposed into mutually independent between-group and within-group variations, it is widely used to measure relative disparities in economic development. Given its suitability for regional decomposition of spatial differences, this paper introduces the index to quantify the spatial variation in water resource utilization. The calculation formula is as follows:

$$\mathrm{T}=\frac{1}{\mathrm{n}}\sum_{\mathrm{i}=1}^{\mathrm{n}}\log\frac{\bar{\mathrm{x}}}{\mathrm{x_i}} \tag{2}$$

Where: this symbol stands for the Sierr coefficient, while $\mathrm{x_i}$ denotes the value associated with the i-th indicator. n denotes the number of subjects in the study. The term $\bar{x}$ denotes the average value of the indicator. The larger the T-value, the greater the degree of imbalance between the indicators.

2.3.2 Grey Relational Analysis

Grey Relational Analysis[14], proposed by Deng Julong, is a multi-factor statistical method that seeks to identify numerical relationships among various systems (or factors) within a system through specific methodologies. Therefore, grey relational analysis enables quantitative assessment of a system's developmental trajectory, making it particularly suitable for analyzing dynamic processes. The computational steps are as follows:

(1) Determine the sequence for analysis

First, it is necessary to identify the reference data sequence reflecting the system's behavioral characteristics and the comparison data sequence influencing the system's behavior. The data sequence representing the system's behavioral characteristics is termed the reference sequence, while the data sequence composed of factors affecting the system's behavior is termed the comparison sequence.

(2) Dimensionalization operation

In grey relational analysis, due to potential differences in the units of measurement for data across the sequences of various system factors, it is typically necessary to perform dimensionless operations on the data.

(3) Calculate the grey correlation coefficient

(4) Calculate the grey correlation degree

$$R_i=\frac{1}{N}\sum_{k=1}^{N}\xi_{i(k)} \tag{3}$$

Where γ is the grey correlation coefficient, the correlation coefficient ranges from 0 to 1. The closer it is to 1, the stronger the relationship between the two indicators, and vice versa. N denotes the number of time series; k meaning as above. When 0 <R_i<0.35, the correlation between the two system indicators is weak; when 0.35<R_i <0.65, the correlation between the two indicators is moderate; when 0.65<R_i<0.85, the correlation between the two indicators is relatively strong; when 0.85<R_i<1, the correlation between the two indicators is extremely strong, and their interaction is extremely strong.

2.3.3 Tapio Decoupling Analysis Method

The Tapio elasticity model is widely used because it provides a concrete numerical representation of the relationship between economic growth and resource-environment interactions, while also being easy to operate. Based on this, this paper employs the Tapio decoupling model to examine the relationship between comprehensive water resource utilization and high-quality economic development across six cities in the Wei River Basin of Shaanxi Province. The formula for calculating the decoupling elasticity coefficient is as follows:

$$R=\Delta W/\Delta GDP=[(WC_n-WC_{n-1})/WC_n]/[(GDP_n-GDP_{n-1})/GDP_n] \quad (4)$$

Where: R denotes the elasticity coefficient; ΔWC-Percentage Change in Annual Water Consumption in the West Wei River Basin; ΔGDP-Percentage Change in GDP of the Wei River Basin, Shaanxi Province; n, n-1-The start and end times of the calculation.

Based on the classification criteria in existing literature[15], decoupling elasticity indices can be categorized into eight types, as shown in *Figure 1*.

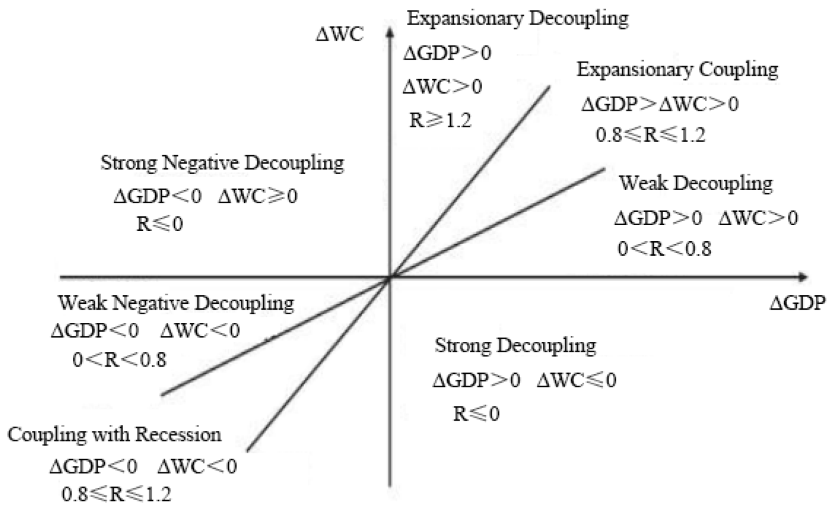

Figure 1: Classification of Indicators in the Tapio Decoupling Model

2.3.4 Data Sources and Indicator Development

The original data in this paper is sourced from the Shaanxi Statistical Yearbook 2000–2021, the Shaanxi Water Resources Bulletin, and the China Economic and Social Development Statistical Database. Water usage types in the Wei River Basin of Shaanxi are categorized according to the classification standards of the Water Resources Bulletin into domestic water use, industrial water use, agricultural water use, and ecological water use. Indicators for high-quality economic development are primarily considered from the perspectives of industrial structure, national economic conditions, urbanization progress, and government fiscal status. Specific indicators are shown in *Figure 2.*

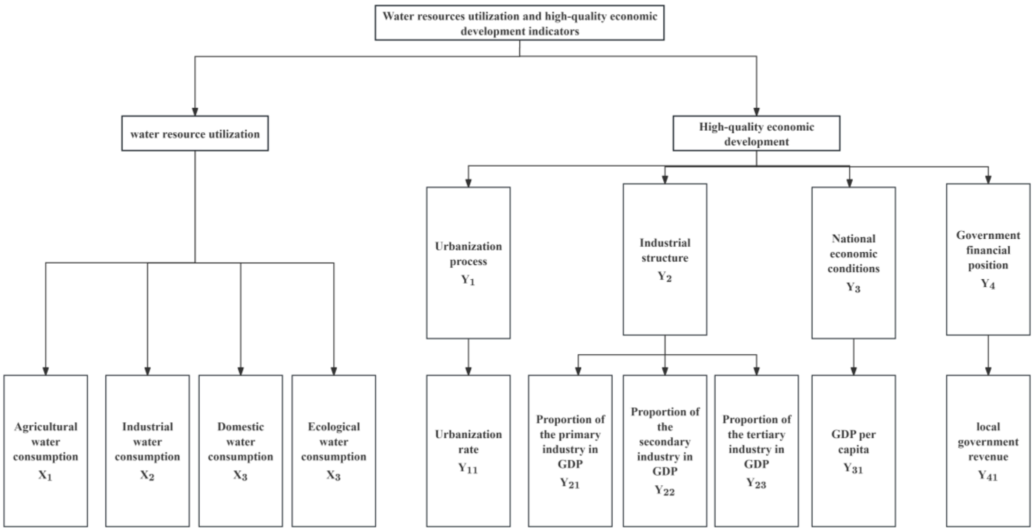

Figure 2: Water Resource Utilization Types and High-Quality Economic Development Indicators

3. Analysis of Spatiotemporal Evolution Characteristics of Water Resource Utilization and High-Quality Economic Development in the Wei River Basin, Shaanxi Province

3.1 Economic Development Status of the Wei River Basin in Shaanxi

3.1.1 Economic Growth Situation

From 2000 to 2021, the gross domestic product (GDP) of the Wei River Basin in Shaanxi Province increased annually, with significant fluctuations in its growth rate. The overall growth rate remained above 10% (Figure 3). Economic growth accelerated rapidly from 2000 to 2008, followed by a sharp decline in 2009 and a swift rebound in 2010. From 2011 to 2015, the growth rate trended downward, reaching its lowest point of 3.19% in 2015. By 2018, growth resumed an upward trajectory, potentially driven by new economic momentum from the rise of short-video platforms. However, the growth rate fell again to a low of 3.42% in 2020 due to the impact of the COVID-19 pandemic and the resulting economic downturn. Economic recovery began in 2021, with the growth rate starting to rebound.

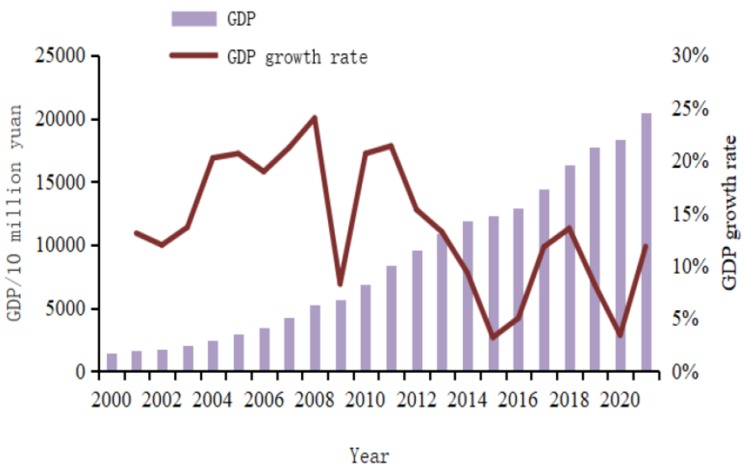

Figure 3: Economic Growth in the Wei River Basin, Shaanxi Province, 2000–2021

3.1.2 Share of Each Industry

The development of the tertiary industry in the Wei River Basin of Shaanxi exhibits structural characteristics (Figures 4):

Primary Industry: Its share of GDP has shown an overall downward trend, declining from 12.86% in 2000 to 7.58% in 2021. However, its value-added has increased annually, rising from 18.086 billion yuan to 155.219 billion yuan.

Secondary Industry: Its share increased from 2000 to 2008 but declined overall after 2009, falling from 44.96% to 41.46%. However, its value-added output continued to grow, rising from 63.242 billion yuan to 848.343 billion yuan, mirroring the trend of the primary industry.

Tertiary Industry: Its overall share increased from 41.28% to 51.08%, with added value growing from 59.33 billion yuan to 1,047.858 billion yuan, becoming the core driver of economic growth.

In the process of industrial restructuring, the secondary sector continues to hold a significant share, while the tertiary sector (particularly services) is accelerating its rise. The primary sector (primarily agriculture, forestry, animal husbandry, and fisheries) has seen output growth, but its expansion rate lags behind, and its share in the economy continues to decline. This trend aligns with the upgrading direction of economic development and people's livelihood needs.

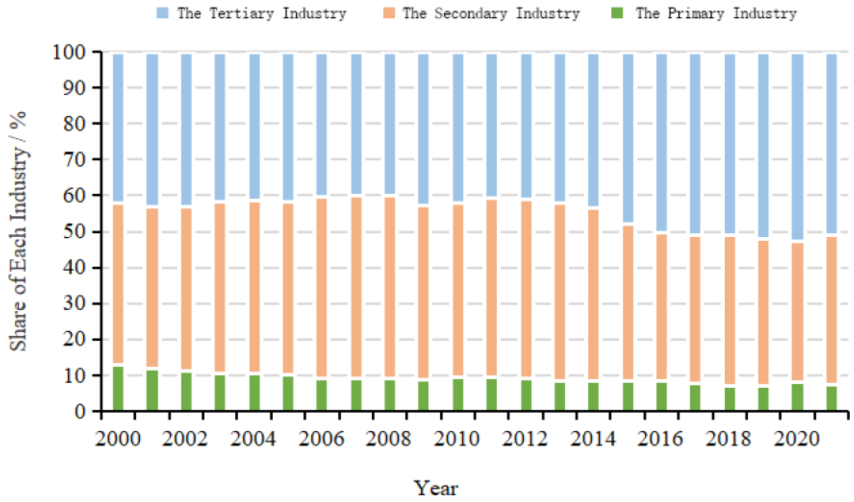

Figure 4: Proportion of Industries in the Wei River Basin, Shaanxi Province, 2000–2021

3.2 Spatio-Temporal Variations in Water Resource Utilization in the Wei River Basin, Shaanxi Province

3.2.1 Total Analysis

A spatial variance analysis was conducted on water consumption data from six cities in the Wei River Basin of Shaanxi Province. The changes in the coefficient of variation and the Sier coefficient are shown in Figures 5 and 6 reveal that both the Sier coefficient and coefficient of variation exhibit relatively high values. This stems from the divergent economic development levels among the six cities in the Shaanxi Weihe River Basin, resulting in significant disparities and spatial imbalances in water resource utilization patterns. The disparity in water resource utilization between total water consumption and agricultural water use is relatively minor. However, regional differences and spatial imbalances in domestic water consumption have been steadily increasing. This is largely due to the emergence of Xi'an as a new first-tier city within the region, which has attracted substantial talent and resources from surrounding areas. Consequently, significant regional disparities and spatial imbalances in water consumption have emerged among cities within the Shaanxi Weihe

River Basin. Conversely, regional disparities and spatial imbalances in industrial water use have progressively diminished. This trend reflects ongoing industrial transformation and upgrading across many cities, narrowing regional differences and consequently reducing industrial water consumption. While industrial water use shows an overall downward trajectory, it experienced a gradual increase from 2009 to 2019, likely influenced by the Western Development Strategy. Cities initially developed industrial sectors, but industrial activity declined after 2019, likely due to the COVID-19 pandemic, leading to sustained industrial downturns. Agricultural water use exhibits greater spatial imbalance. This stems from the complex and diverse geographical conditions of the Wei River Basin in Shaanxi Province. Some cities possess ample land suitable for agricultural development, while others, such as Yan'an, have limited arable land. Consequently, agricultural water use shows a high degree of spatial unevenness. However, the magnitude of these differences remains relatively small. This is because the water usage patterns and development approaches for agriculture in this region are largely consistent.

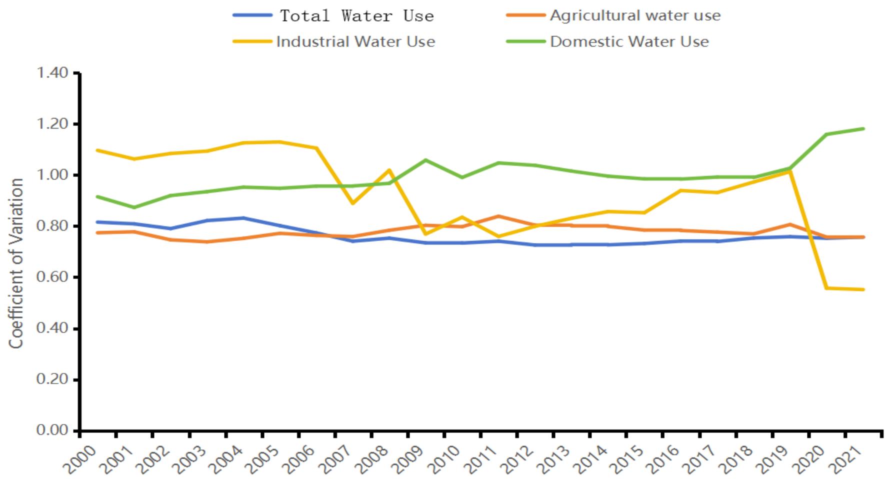

Figure 5: Variation in the Coefficient of Variation of Water Use in the Wei River Basin, Shaanxi Province, 2000–2021

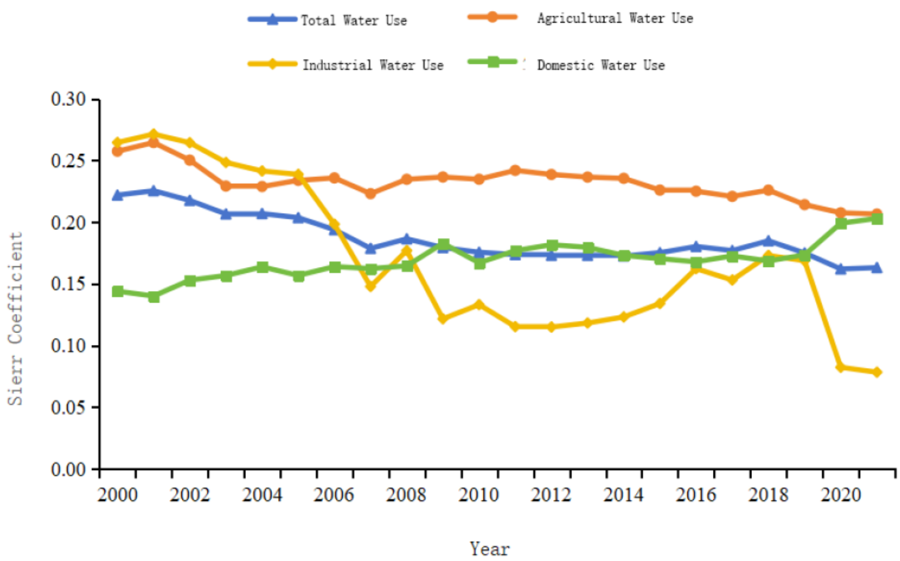

Figure 6: Changes in the Sier Coefficient of Water Use in the Wei River Basin, Shaanxi Province, 2000–2021

3.2.2 Efficiency Analysis

Sierr coefficients and coefficients of variation were analyzed for water consumption per 10,000 yuan of GDP and other data across six cities in the Wei River Basin of Shaanxi Province. The results are shown in Figures 7 and 8. The magnitude of the coefficient of variation and the Sierr coefficient indicates significant spatial disparities in water use efficiency across the six prefecture-level cities in the Weihe River Basin, Shaanxi Province. The spatial variation coefficients for both indicators related to water consumption per 10,000 yuan of GDP were the highest, highlighting pronounced interregional differences and uneven spatial distribution. The trend in the coefficient of variation shows that water consumption per 10,000 yuan of industrial added value exhibits an overall decreasing trend with a significant rate of decline, indicating that differences are continuously narrowing. Water consumption per 10,000 yuan of GDP showed an overall decreasing trend, though it experienced a brief upward trend between 2004 and 2006. Water consumption per 10,000 yuan of agricultural added value also exhibited an overall decreasing trend, but it showed significant increases during the periods from 2003 to 2005 and from 2007 to 2012.

In terms of the absolute value of the Sierr coefficient, the spatial distribution of water consumption per ten thousand yuan of agricultural added value exhibits the greatest imbalance, followed by water consumption per ten thousand yuan of GDP, and finally water consumption per ten thousand yuan of industrial added value. Regarding trends, all three indicators show an overall downward trajectory, indicating that the spatial distribution imbalance is gradually narrowing.

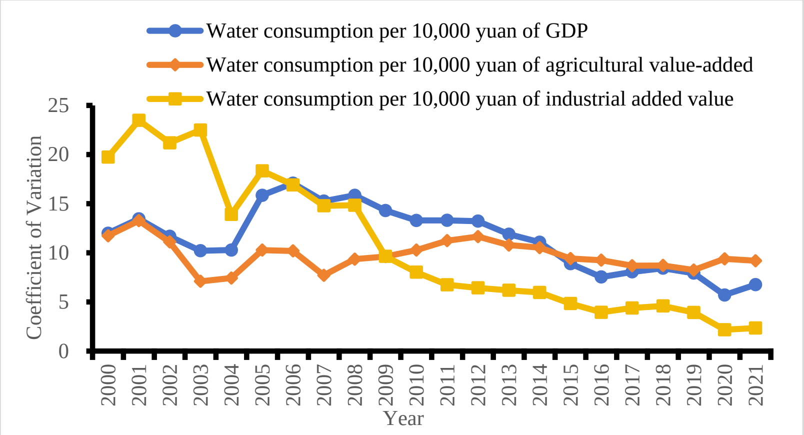

Figure 7: Variation in the Coefficient of Variation for Water Use Efficiency in the Wei River Basin, Shaanxi Province, 2000–2021

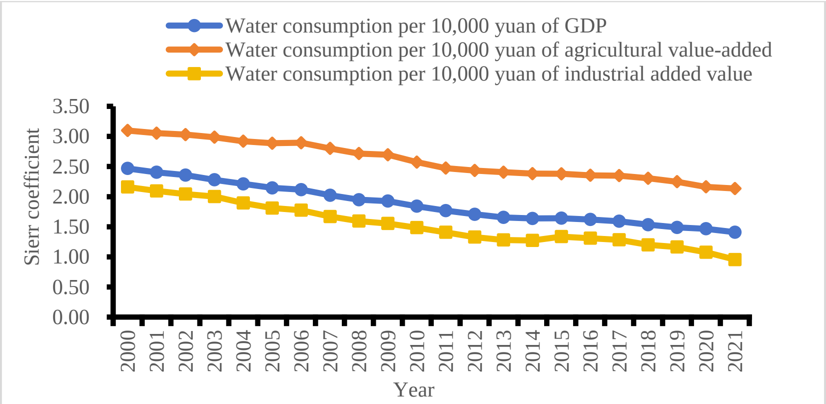

Figure 8: Changes in the Sierr Coefficient of Water Use Efficiency in the Wei River Basin, Shaanxi Province, 2000-2021

3.3 Grey Relational Degree Analysis

Gray correlation analysis was employed to measure the interrelationship between water resource utilization and high-quality economic development indicators across six prefecture-level cities in the Wei River Basin of Shaanxi Province. The results are presented in Figures 9 and 10.

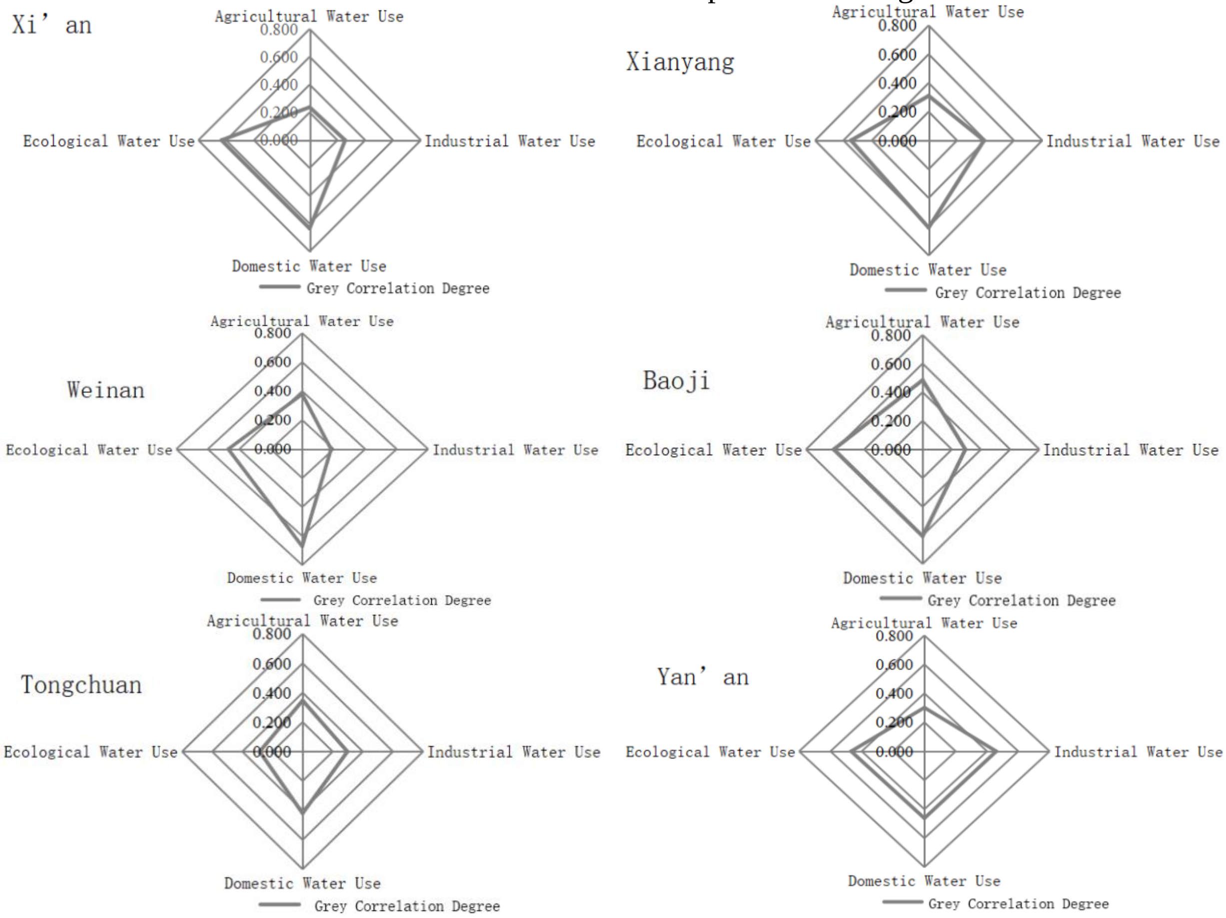

Figure 9: Grey Correlation Degree of Water Resource Utilization Types in the Wei River Basin, Shaanxi Province, with High-Quality Economic Developmen

An analysis of the correlation between water resource utilization types and high-quality economic development indicators across cities was conducted. As shown in Figure 9, the six prefecture-level cities in the Wei River Basin of Shaanxi exhibit varying degrees of grey correlation between their high-quality economic development indicators and water resource utilization types, specifically manifested as follows:

(1) Xi'an: Domestic Water Use (0.635) > Ecological Water Use (0.634) > Industrial Water Use (0.255) > Agricultural Water Use (0.238)

(2) Xianyang: Domestic Water Use (0.606) > Ecological Water Use (0.547) > Industrial Water Use (0.39) > Agricultural Water Use (0.311)

(3) Weinan: Domestic Water Use (0.671) > Ecological Water Use (0.47) > Agricultural Water Use (0.379) > Industrial Water Use (0.182)

(4) Baoji: Ecological Water Use (0.61) > Domestic Water Use (0.606) > Agricultural Water Use (0.485) > Industrial Water Use (0.293)

(5) Tongchuan: Domestic water use (0.42) > Agricultural water use (0.347) > Industrial water use (0.297) > Ecological water use (0.285)

(6) Yan'an: Ecological Water Use (0.468) > Domestic Water Use (0.462) > Industrial Water Use

(0.459) > Agricultural Water Use (0.302)

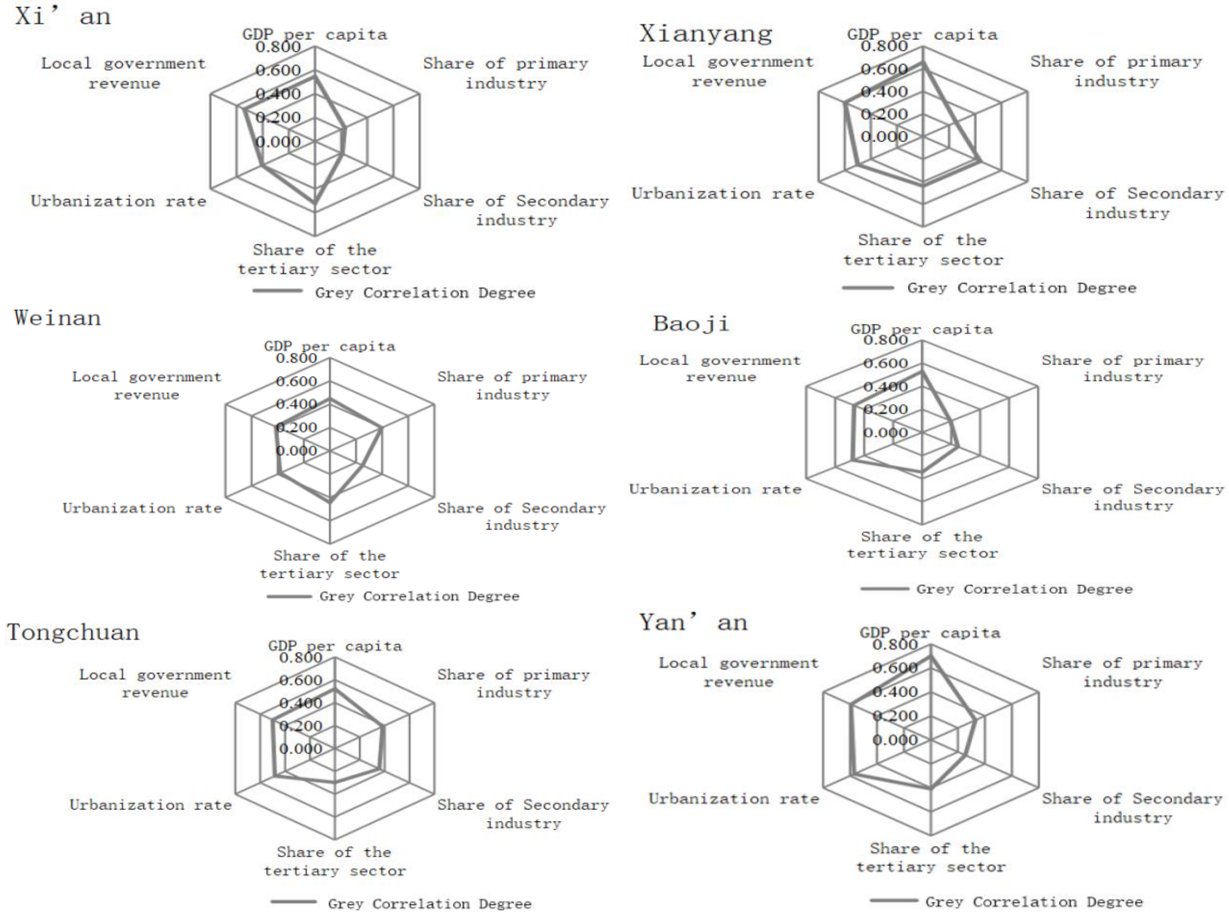

Figure 10: Grey Correlation Analysis of Water Resource Utilization Types for High-Quality Economic Development in the Wei River Basin, Shaanxi Province

This disparity stems from the interplay between different water usage types and the high-quality economic development of various cities: shifts in water consumption patterns reflect economic development characteristics, while conversely, socioeconomic progress also influences water usage. For instance, domestic water consumption in Xi'an, Xianyang, and Weinan exhibits the strongest correlation with indicators of high-quality economic development, indicating that domestic water usage is significantly impacted by urban development, with changes in consumption directly reflecting the dynamics of high-quality economic growth. Simultaneously, we should note that ecological water use ranks second in correlation with the overall high-quality economic development of the city. This is because, for these three cities, ecological water use plays a role in water source conservation, water resource purification, water resource recycling, and shaping a favorable economic development environment. In Baoji and Yan'an, ecological water use exhibits the strongest correlation with high-quality economic development indicators, indicating its paramount importance to these cities' economic advancement. The differing correlations of subsequent water categories also reflect distinct development priorities: while Yan'an is better suited for industrial growth beyond its tertiary sector, Baoji leans more toward agriculture. Tongchuan shows the highest grey correlation for domestic and agricultural water use, reflecting the significant influence of industrial and agricultural water consumption on its high-quality economic development.

Investigate the correlation between indicators of high-quality economic development and water resource utilization patterns. According to the data in Figure 10, the grey correlation coefficients between per capita GDP, local fiscal revenue, and water resource utilization in Xi'an are 0.545 and 0.54, respectively, indicating that these two indicators exert the most significant influence on water resource utilization in Xi'an. The indicators exerting the greatest influence on Xianyang's water resource utilization are per capita GDP (0.657), local fiscal revenue (0.599), and urbanization rate (0.5). For Weinan, the most influential indicators are per capita GDP (0.449), tertiary industry share (0.455), and local fiscal revenue (0.414). The indicators with the greatest impact on Baoji City's water resource utilization were per capita GDP (0.529), urbanization rate (0.48), and local fiscal revenue (0.47). For Tongchuan City, the most influential indicators were per capita GDP (0.522), local fiscal revenue (0.5), and urbanization rate (0.483). The indicators with the strongest influence on water resource utilization in Yan'an City are per capita GDP (0.7), local fiscal revenue (0.593), and urbanization rate (0.57). Comprehensive analysis indicates that indicators reflecting national economic conditions and government fiscal status exhibit the highest correlation with water resource utilization.

4. Analysis of the Decoupling Between Water Resource Utilization and High-Quality Economic Development in the Wei River Basin, Shaanxi Province

Due to incomplete water resource data for Shaanxi Province in 1999, calculations were performed using the decoupling elasticity model based on data such as the rate of change in total water use and GDP growth rate in the Wei River Basin of Shaanxi Province from 2001 to 2021 (see Table 1). The results are as follows:

1) Overall Decoupling Relationship: The overall decoupling relationship between water resource utilization and high-quality economic development in the Wei River Basin of Shaanxi Province is characterized by both strong and weak decoupling: Strong Decoupling (9 years): 2001, 2002, 2003, 2007, 2009, 2010, 2016, 2019, 2020 Characterized by reduced water resource utilization alongside sustained economic growth, representing the most ideal relationship. Weak decoupling (remaining years): Water resource utilization growth lagged behind economic growth, constituting a suboptimal state.

2) Agricultural Water Use and Primary Industry: Decoupling Performance: Over 21 years, 12 instances of strong decoupling, 8 instances of weak decoupling, and 1 instance of negative expansion decoupling (2006) occurred. Analysis of Causes: Agricultural water use fluctuates significantly, while the primary industry's growth rate remains relatively stable. In 2006, an unfavorable negative decoupling occurred as the rate of change in agricultural water use exceeded the primary industry growth rate (decoupling elasticity of 1.3).

3) Industrial Water Use and Secondary Industry: Decoupling Performance: 10 instances of strong decoupling, 8 instances of weak decoupling, 2 instances of recession decoupling (2016, 2020), and 1 instance of strong negative decoupling (2015). The strong negative decoupling in 2015 reflects the dual deterioration of industrial negative growth and increased water resource consumption, representing the worst-case scenario. The recession decoupling in 2016 and 2020 indicates that industrial water use efficiency urgently needs improvement, which can be achieved by increasing water reuse rates.

4) Domestic Water Use (Service Sector) and Tertiary Industry: Decoupling Pattern: Primarily characterized by 14 instances of weak decoupling, accompanied by 4 instances of strong decoupling, 2 instances of expansion coupling (2020-2021), and 1 instance of expansion negative decoupling. The period 2020-2021 exhibited expansion coupling, where the growth rate of domestic water consumption largely mirrored that of the tertiary sector. This suboptimal coordination highlights the need to optimize water usage structures. This phenomenon stemmed from the COVID-19 pandemic's impact during 2020-2021: prolonged home confinement led to a rapid surge in

household water consumption, while the service sector experienced slow growth, stagnation, or even contraction. The decoupling elasticity coefficient for the service sector in expansion-negative decoupling was 3.4, but this state is undesirable.

Table 1: Decoupling Relationship and Decoupling Elasticity Index Between Water Resource Utilization and High-Quality Economic Development in the Wei River Basin, Shaanxi Province

Year	Overall Decoupling Resilience	Agricultural Decoupling Resilience	Industrial Decoupling Resilience	Service Sector Decoupling Resilience	Total Decoupling Relationship	Agricultural Decoupling Relationship	Industrial Decoupling Relationship	Service Sector Decoupling Relationship
2001	-0.16	-0.53	-0.13	0.10	strong decoupling	strong decoupling	strong decoupling	weak decoupling
2002	-0.13	-0.59	-0.09	0.39	strong decoupling	strong decoupling	strong decoupling	weak decoupling
2003	-0.45	-1.63	0.31	-0.58	strong decoupling	strong decoupling	weak decoupling	strong decoupling
2004	0.21	0.18	-0.17	0.57	weak decoupling	weak decoupling	strong decoupling	weak decoupling
2005	0.20	0.46	-0.01	0.08	weak decoupling	weak decoupling	strong decoupling	weak decoupling
2006	0.48	1.30	0.15	0.15	weak decoupling	Expansionary decoupling	weak decoupling	weak decoupling
2007	-0.29	-0.21	-0.72	-2.03	strong decoupling	strong decoupling	strong decoupling	strong decoupling
2008	0.27	0.21	0.49	3.40	weak decoupling	weak decoupling	weak decoupling	expansionary decoupling
2009	-0.23	-0.08	-6.13	0.61	strong decoupling	strong decoupling	strong decoupling	weak decoupling
2010	-0.06	-0.14	0.42	-0.13	strong decoupling	strong decoupling	weak decoupling	strong decoupling
2011	0.15	0.01	0.06	0.60	weak decoupling	weak decoupling	weak decoupling	weak decoupling
2012	0.01	0.02	-0.19	0.11	weak decoupling	weak decoupling	strong decoupling	weak decoupling
2013	0.08	-0.22	0.19	0.21	weak decoupling	strong decoupling	weak decoupling	weak decoupling
2014	0.23	0.24	0.41	0.10	weak decoupling	weak decoupling	weak decoupling	weak decoupling
2015	0.51	-0.49	-0.74	-0.09	weak decoupling	strong decoupling	strong negative decoupling	strong decoupling
2016	-0.22	-0.22	8.39	0.63	strong decoupling	strong decoupling	decoupling from decline	weak decoupling
2017	0.21	0.43	0.18	0.24	weak decoupling	weak decoupling	weak decoupling	weak decoupling
2018	0.05	-0.55	-0.08	0.18	weak decoupling	strong decoupling	strong decoupling	weak decoupling
2019	-0.68	-0.93	-0.78	0.07	strong decoupling	strong decoupling	strong decoupling	weak decoupling
2020	-1.99	-0.42	442.97	1.07	strong decoupling	strong decoupling	decoupling from decline	expansionary coupling
2021	0.25	0.01	-0.13	0.92	weak decoupling	weak decoupling	strong decoupling	expansionary coupling

The above findings indicate that the region still faces relatively low water utilization efficiency in the service sector, necessitating measures such as injecting new momentum into service industry development to enhance water resource utilization rates. In summary, the decoupling trend between water resource utilization and economic growth in the Wei River Basin of Shaanxi Province continues to strengthen, with decoupling elasticity exhibiting the following hierarchy: industrial > agricultural > overall > service sectors.

5. Conclusions and Recommendations

5.1 Conclusions

(1) Based on calculations and analysis using the Sierr coefficient and coefficient of variation, research on the spatial distribution of different water usage types across prefecture-level cities in the Wei River Basin of Shaanxi Province reveals that spatial variations in domestic water consumption are most pronounced, while spatial imbalances in agricultural water use are notably significant. In terms of trends, the spatial imbalance and variation in industrial water consumption relative to the basin's total water use have generally narrowed. This is closely linked to the rapid improvement in water use efficiency driven by rising urban economic development levels and technological progress, with spatial disparities in water use efficiency gradually diminishing. Regarding specific indicators: - Spatial variation in water consumption per 10,000 yuan of industrial added value has significantly narrowed after fluctuations. - Water consumption per 10,000 yuan of GDP has generally stabilized in recent years. - Spatial imbalance in water consumption per 10,000 yuan of agricultural added value remains the highest among all indicators, though the degree of imbalance continues to decrease.

(2) Gray correlation analysis indicates a strong association between water resource utilization and indicators of high-quality economic development in the Wei River Basin of Shaanxi Province. Among these factors, per capita GDP and government fiscal revenue exert the most significant influence on water resource consumption. At the city level, domestic water consumption plays the most prominent role in driving high-quality economic development in Xi'an, Weinan, Xianyang, and Tongchuan, while ecological water consumption holds the greatest significance in Baoji and Yan'an.

(3) Overall, during the 21-year period from 2001 to 2021, the decoupling relationship between water resource utilization and high-quality economic development in the Wei River Basin of Shaanxi Province primarily manifested as weak decoupling. The total decoupling coefficient fluctuated within the range of -1.99 to 0.48. Analyzing by industrial structure, the correlation between water resource utilization and economic growth in the industrial and agricultural sectors was more favorable than the overall relationship between water resource utilization and economic growth. The relationship between overall water resource utilization and economic growth was superior to that observed in the service sector.

5.2 Suggestions

(1) Rationally optimize the industrial structure. Addressing the issue that the primary industry in Shaanxi's Weihe River Basin contributes the lowest share of output value while accounting for a high proportion of agricultural water use, it is necessary to reduce water consumption per unit of output through economic restructuring. Specifically, industries incompatible with the basin's economic development should be phased out, while vigorously developing a green economy, promoting clean production models, actively cultivating water-efficient industrial systems, and gradually eliminating low-value-added, high-water-consumption sectors. Regarding industrial weight adjustments, the share of the primary sector should be reasonably reduced while prioritizing the enhancement of development quality in the secondary and tertiary sectors. This approach will foster a virtuous cycle of coordinated development between water resource utilization and economic growth.

(2) Enhancing Water Resource Utilization Efficiency. To achieve coordinated economic and ecological development in the Wei River Basin of Shaanxi Province, water resource utilization efficiency must be improved across multiple dimensions. In the agricultural sector, production layouts should be dynamically optimized based on regional economic and water-soil resource conditions. Crop planting structures should be scientifically planned to avoid blind expansion, while irrigation technologies should be innovated. Water-saving methods such as drip irrigation and sprinkler irrigation should be promoted, with precise control over irrigation scale. Industrial water conservation can be advanced through three approaches: accelerating industrial restructuring and upgrading to phase out high-water-consumption production capacities and promote green, low-carbon development; establishing water-saving enterprises as a goal, building water recycling systems, and achieving efficient water resource circulation through projects like wastewater treatment reuse, reclaimed water substitution, and pipeline network upgrades; and intensifying R&D and promotion of water-saving technologies, introducing advanced equipment, and establishing specialized technical service platforms. For domestic water use, cities should improve water recycling systems and strengthen refined management of public water resources, while rural areas should promote water-saving fixtures and improve water usage habits. Concurrently, multi-channel public education should enhance water conservation awareness, guiding society to embrace water-saving practices and ensuring the implementation of water conservation principles.

(3) Strengthen Policy Guidance and Technological Innovation: Governments can implement relevant policies to encourage enterprises, institutions, and individuals to actively participate in water resource conservation and efficiency. Simultaneously, by enhancing technological innovation, developing and applying more efficient, environmentally friendly, and safe water resource utilization technologies and equipment, they can provide technical support for improving water resource utilization rates.

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