The user is asking me to translate a Chinese academic paper title: "1990—2020 年新疆用水量时空演化格局及影响因素分析后印本" Let me break this down: - 1990—2020 年: 1990-2020 - 新疆: Xinjiang - 用水量: water consumption / water use - 时空演化格局: spatiotemporal evolution pattern - 及: and - 影响因素: influencing factors / driving fact…

Authors: Liu, The user has provided a single name: "孙思奥". This is a Chinese name. The task is to translate it according to the instructions for scientific academic translation.

Let me analyze the requirements: 1. This is not a paragraph with tags 2. It' s not a mathematical expression or LaTeX content 3. It' s a proper name

The glossary provided only includes: - 机器学习 => machine learning - 深度学习 => deep learning

There' s no instruction for translating personal names. In academic contexts, Chinese names are typically transliterated using Pinyin. "孙思奥" would be "Sun Si' ao" in Pinyin.

However, I need to check if there are any specific rules in the instructions about names. The instructions say: - "Translate from Simplified Chinese to English with the highest accuracy and academic tone"- "Preserve ALL LaTeX commands and placeholders exactly" - "Preserve ALL citation commands ([?], ??, (??), etc.) exactly"- "PRESERVE ALL …paragraph wrapper tags EXACTLY"- "Use precise technical terminology - obey the glossary strictly"

Since this is just a name without any tags, LaTeX, or citations, and it' s not in the glossary, I should translate it appropriately. In academic writing, Chinese names are typically rendered in Pinyin with the surname first, often with the surname in all caps or separated from the given name. Common formats are: - SUN Si' ao - Sun Si' ao - Si' ao Sun (Western order)

The most standard academic format for Chinese names in English publications is either "Sun Si' ao" or "Si' ao Sun". Given that the original is in Chinese order (surname first), "Sun Si' ao" would be most faithful. Sometimes hyphens or spaces are used in given names: “Si Ao” or “Si-Ao”. “思奥” is two characters, so “Si’ ao” or “Si Ao” would be appropriate. The apostrophe version “Si’ ao” is common to show the two-character given name.

Since there are no tags or other structural elements, I should just provide the translated name directly. The instructions say “Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent).”

So the output should simply be: Sun Si’ ao

Wait, let me, The user has provided “方创琳” which is a Chinese name. This is not a paragraph with tags, LaTeX commands, or any of the complex formatting mentioned in the instructions. It’ s simply a name.

According to the instructions: - I should translate from Simplified Chinese to English - Preserve ALL LaTeX commands and placeholders - Preserve ALL citation commands - **PRESERVE ALL ···paragraph wrapper tags EXACTLY** - Maintain academic tone - Use precise technical terminology from the glossary - The glossary only contains: 机器学习 => machine learning and 深度学习 => deep learning - Return ONLY the translated text - Keep one output paragraph per input paragraph - **Maintain exact count and IDs of ···tags**

Since the input is just a name “方创琳” without any tags or other formatting, I need to consider what to do. The name appears to be a personal name, likely a researcher or author. In academic contexts, Chinese names are typically transliterated using Pinyin.

“方创琳” would be transliterated as “Fang Chuanglin” (surname first, then given name). In some contexts, it might be written as “Chuanglin Fang” (Western order), but in academic papers, especially when referring to Chinese authors, the original order (Fang Chuanglin) is often preserved.

However, the instructions are very specific about preserving tags. Since there are no tags in the input, I should just provide the transliteration of the name.

But wait - the instructions say “Return ONLY the translated text for the given input”. The input is just “方创琳”. There’ s no paragraph structure to preserve. I should just output the English transliteration.

Let me check if there are any edge cases: - Is this a test to see if I follow instructions when there are no tags? - Should I wrap it in a tag? The instructions say “PRESERVE ALL ···paragraph wrapper tags EXACTLY” - but there are none to preserve. - The instructions say “if input has N paragraph tags, output must have exactly N paragraph tags with matching IDs” - here N=0, so output should have 0 paragraph tags.

So I should just output, The user has provided a single Chinese character “周迪”. This appears to be a name. The instruction says to translate from Simplified Chinese to English with academic tone, preserving all LaTeX, citations, and tags.

However, the input "周迪" is just a name. It doesn' t contain: - LaTeX commands - placeholders - Citation commands ([?], **??**, (**??**)) - ···tags - Academic content - Section structure - Mathematical expressions

The glossary provided is: - 机器学习 => machine learning - 深度学习 => deep learning

But "周迪" is not in the glossary. It' s a proper name.

According to the instructions, I should: 1. Preserve ALL LaTeX commands and placeholders exactly 2. Preserve ALL citation commands exactly 3. **PRESERVE ALL ···paragraph wrapper tags EXACTLY** 4. Maintain academic tone and formal scientific writing style 5. Use precise technical terminology - obey the glossary strictly 6. Preserve section structure and paragraph organization 7. Translate all content completely - do not omit any information

Since there are no tags in the input, I need to consider what to do. The instructions say "Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent)." and "Keep one output paragraph per input paragraph; do not merge or split paragraphs."

But there are no paragraphs in the input. It's just a name. The most reasonable interpretation is that I should translate the name as is, which would be "Zhou Di" (standard pinyin romanization for Chinese names).

However, the instructions also say "PRESERVE ALL ···paragraph wrapper tags EXACTLY" and "Maintain exact count and IDs of ···tags - if input has N paragraph tags, output must have exactly N paragraph tags with matching IDs" .

Since there are 0 tags in the input, the output should have 0 tags. So I should just output the translated name.

But wait - the system prompt says "You are a professional scientific translator specializing in academic papers." and the user provided "周迪" . This could be part of a larger document that was, The user has provided a single Chinese character "鲍超" . This appears to be a name. Let me analyze the context:

1. The user previously gave me instructions about translating scientific papers with specific requirements about preserving LaTeX, citations, and tags.
2. Now they just provide "鲍超" which is a Chinese name.
3. The name "鲍超" could be:
   - A person' s name (Bao Chao)
   - Or potentially something else, but most likely a name

Given the previous context about scientific translation, the user might be: - Testing if I recognize this as a name that might appear in a scientific paper - Asking for translation of this specific term - This could be a historical figure, a modern researcher, etc.

"鲍超" is: - 鲍 (Bao) - a Chinese surname - 超 (Chao) - a given name meaning "super" or "transcend"

In academic/scientific contexts, Chinese names should be transliterated following standard pinyin conventions. The correct transliteration is "Bao Chao" .

However, I need to consider if this is a specific historical figure. There was a general named 鲍超 (Bao Chao) in the late Qing Dynasty who fought in the Taiping Rebellion. But without more context, I should just provide the standard transliteration.

Since the user gave me strict instructions about translation format, but this is just a name without any tags or LaTeX, I should just provide the direct translation/transliteration.

The most appropriate response is simply: Bao Chao

But wait, let me reconsider the instructions. The user said: "Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent)."

So I should just output "Bao Chao" without any additional text.

However, I should also consider if this might be part of a larger text that got cut off. But based on what' s provided, I can only translate what' s given.

The name "鲍超" in pinyin is "Bao Chao" . In academic contexts, it' s common to write Chinese names with the surname first, so "Bao Chao" is correct.

Let me check if there are any special cases: - If this is a historical figure, the same transliteration applies - If this is a modern researcher, the same transliteration applies - The character "超" is common in, The user has provided a single name: "孙思奥" . This is a Chinese name. The task is to translate it according to the instructions for scientific academic translation.

Let me analyze the requirements: 1. This is not a paragraph with tags, LaTeX, or citations 2. It' s a proper name that appears to be a person' s name 3. The glossary provided only covers "机器学习 => machine learning" and "深度学习 => deep learning" , which are not relevant here 4. The general instruction is to translate from Simplified Chinese to English with highest accuracy and academic tone

For Chinese names in academic contexts, the standard practice is: - Use Pinyin transliteration - Family name first, given name second (maintaining Chinese order) - Capitalize the first letter of each part - No spaces between the family name and given name in academic writing (though sometimes a space is added)

"孙思奥" would be transliterated as "Sun Si' ao" or "Sun Siao" or "Sun Si-ao" . The most standard Pinyin is "Sun Si'ao" where the apostrophe separates syllables that might otherwise be ambiguous. However, in many academic contexts, Chinese names are simply written as "Sun Si' ao" or even "Sun Siao" without the apostrophe.

Let me consider the most common academic conventions: - Sun Si' ao (with apostrophe) - Sun Si Ao (with space) - Sun Siao (combined given name)

The most formally correct Pinyin transliteration would be "Sun Si' ao" where the apostrophe indicates the separation between "si" and "ao" to prevent confusion with "siao" . However, in many modern academic publications, the apostrophe is omitted and it' s written as "Sun Si' ao" or "Sun Si Ao" .

Given that this is a name and the instructions say to translate with highest accuracy and academic tone, I should provide the standard academic transliteration. The most common and accepted form in academic literature would be "Sun Si' ao" or "Sun Si Ao" .

Actually, looking at academic style guides: - For Chinese names, the family name is kept first - The given name is transliterated in Pinyin - The given name' s characters are typically written together or hyphenated: "Sun Siao" or "Sun Si-ao" or "Sun Si' ao"

The most standard approach in modern academic publishing is to use Pinyin without apostrophes or hyphens unless

Date: 2024-09-25T00:00:00+00:00

Abstract

Drought and water scarcity are fundamental characteristics of Xinjiang' s physical geography. Understanding the spatiotemporal evolution patterns of water use and their influencing factors is a prerequisite for water resources demand management. Using the Logarithmic Mean Divisia Index (LMDI) method, this study analyzes the influencing factors of temporal variation trends and spatial differentiation patterns of water consumption in Xinjiang from 1990 to 2020, and examines the main reasons why its per capita water consumption is higher than other regions in Northwest China and the national average. The results show that: (1) Xinjiang' s total water consumption first increased and then decreased, while per capita water consumption showed an overall declining trend. (2) Changes in water use intensity and industrial structure are the main factors driving the decline in Xinjiang' s total water consumption. (3) Higher water use intensity and an agriculture-dominated industrial structure are the main reasons why Xinjiang' s per capita water consumption is significantly higher than other regions in Northwest China and the national average. (4) There are large spatial differences in per capita water consumption in Xinjiang, mainly due to differences in water use intensity, per capita GDP, and industrial structure.

Full Text

Spatiotemporal Evolutionary Patterns and Influencing Factors of Water Use in Xinjiang from 1990 to 2020

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Abstract

Drought and water scarcity are fundamental characteristics of Xinjiang's natural geography. Understanding the spatiotemporal evolutionary patterns of water use and their influencing factors is essential for effective water resources demand management. This study employs the logarithmic mean Divisia index (LMDI) method to analyze the factors driving temporal trends and spatial heterogeneity in water use in Xinjiang from 1990 to 2020, and identifies the primary reasons why Xinjiang' s per capita water use exceeds that of other northwestern regions and the national average. The results indicate: (1) Xinjiang' s total water use exhibited an initial increase followed by a decrease, while per capita water use showed an overall declining trend. (2) Declining water use intensity and changing industrial structure were the main factors contributing to the reduction in total water use. (3) High water use intensity and an agriculture-dominated industrial structure were the primary reasons why Xinjiang' s per capita water use far exceeds the average levels of other northwestern regions and the nation as a whole. (4) Significant spatial variation in per capita water use across Xinjiang was mainly attributable to differences in water use intensity, per capita GDP, and industrial structure. Based on these findings, we propose relevant water management policy recommendations to provide scientific support for sustainable water resources development and utilization in Xinjiang.

Keywords: water resources management; logarithmic mean Divisia index (LMDI) method; water resources exploitation; spatial heterogeneity; Xinjiang

Introduction

Drought and water scarcity are defining features of Xinjiang, which is located in the arid interior of the Eurasian continent, far from moisture sources. The region experiences an arid climate with scarce rainfall and strong evaporation, with an average annual precipitation of only 158 mm and evaporation of approximately 2000 mm. As a typical irrigation agriculture region, agricultural water use has long accounted for over 90% of total socioeconomic water consumption. With population growth and socioeconomic development, water demand has continuously increased, encroaching upon ecological water allocations and causing river depletion, lake shrinkage, and expanding groundwater depression cones, which severely threaten the already fragile ecological environment. Water scarcity has become one of the most critical constraints on sustainable socioeconomic development in Xinjiang.

Quantitative analysis of water use changes commonly employs structural decomposition and index decomposition methods. The logarithmic mean Divisia index (LMDI) method is widely used due to its decomposition without residual effects, with applications in carbon emissions, energy consumption, environmental change, and water use analysis. Previous studies have applied LMDI to analyze water use changes across different regions of China, including the western region, northwestern region, Yangtze River Economic Belt, specific river basins (Huaihe, Yellow River), provinces (Liaoning, Shaanxi), and sectors (agricultural irrigation, industry, domestic use). For example, Wu et al. found that economic and population growth drove production water use increases in western China, while industrial structure and water intensity effects inhibited growth. Zhang et al. decomposed production water use differences in northwestern provinces into intensity, structure, income, and population effects, revealing significant spatiotemporal heterogeneity. Yang et al. decomposed Xinjiang' s production water use changes from 1990-2014 into five factors, concluding that economic development and population expansion were the main drivers of growth.

However, existing research has primarily focused on regional production water use or single-sector historical trends, examining influencing factors mainly in the temporal dimension, with less attention to spatial differences within study regions or between regions with similar geographic conditions. Although some studies have analyzed driving factors of water use changes in northwestern China and Xinjiang, systematic analysis of the spatiotemporal evolution mechanisms of total water use (including production, domestic, and ecological water) and per capita water use in Xinjiang remains limited. This study addresses this gap by employing the LMDI method to quantify the contributions of water use intensity, industrial structure, per capita GDP, population, per capita domestic water use, and ecological water use to temporal trends and spatial differences in Xinjiang' s water use from 1990-2020. Using northwestern China (excluding Xinjiang) and national average levels as benchmarks, we further analyze the reasons for Xinjiang' s high per capita water use, providing scientific support for sustainable water management.

1. Materials and Methods

1.1 Study Area

This study examines Xinjiang Uygur Autonomous Region and its 14 prefecture-level cities/autonomous prefectures, including 3 county-level cities directly under regional administration (Shihezi City). Xinjiang covers approximately 1.66 million km^2 (17.3% of China' s total area) but possesses only 3-5% of the nation’ s water resources. Water resources exhibit a spatial pattern of “high in the north and west, low in the south and east; high in mountainous areas, low in plains,” which mismatches economic development and population distribution. Economically developed areas like the northern Tianshan slope have lower per capita water resources—in 2020, Shihezi, Karamay, and Urumqi had per capita water resources below 500 m^3, while Altay, Kizilsu Kirghiz Autonomous Prefecture, and Bayingolin Mongol Autonomous Prefecture exceeded 8000 m^3. Water resource development intensity (ratio of water use to total water resources) exceeds the international water scarcity warning line (40%) in 11 prefectures, with some areas facing severe water shortages.

The user wants me to translate a specific section from Chinese to English. The section is “### 1.2 Data Sources” . Let me analyze the text:

The text is: “### 1.2 Data Sources

Data include total water use and sectoral water use, gross domestic product (GDP), and population for Xinjiang and its prefectures. Water use data for Xinjiang (1990–2020) were obtained from the Xinjiang Water Resources Bulletin, Xinjiang Statistical Yearbook, and related literature. Prefecture-level sectoral water use data were available from 2004 onward due to publication and statistical 口径 changes. GDP data (in constant 2000 prices) and population data were sourced from the Xinjiang Statistical Yearbook and national population census data. Benchmark data for northwestern China (Qinghai, Gansu, Shaanxi, Ningxia) and the nation were obtained from respective water resources bulletins and statistical yearbooks.”

Wait, this text is already in English! The user says “Chinese characters found: 径, 口” but I don’ t see any Chinese characters in this text. The only potential issue is “统计口径” which appears to be partially translated as “statistical 口径” . The character “径” is not present, but “口” is part of “口径” .

Let me re-read the instructions: - “Chinese characters found: 径, 口” - these appear to be examples of what might be found - “These appear to be: mixed technical content and proper nouns” - “DO NOT leave any Chinese characters - not even one”

The text provided has “statistical 口径” which contains the Chinese character “口” as part of “口径” . This needs to be translated. “口径” in this context means “standards” or “criteria” or “definitions” . “统计口径” means “statistical standards” or “statistical definitions” or “statistical scope” .

So I need to translate “statistical 口径” to English. The most appropriate translation would be “statistical standards” or “statistical definitions” . In academic literature, “statistical 口径” is often translated as “statistical standards” or “statistical definitions” or “statistical scope” . Let me think about the context: “due to publication and statistical 口径 changes” - this means changes in how statistics were defined or measured. So “statistical standards” or “statistical definitions” would work well.

The rest of the text is already in English, so I just need to fix that one partial Chinese term.

Let me check if there are any other issues: - The structure should remain the same: "### 1.2 Data Sources" - The content should flow naturally - All the data sources and terms seem appropriate

So my translation will be to replace "statistical 口径" with an appropriate English term. I'll use "statistical standards" as it's commonly used in academic literature.

The final translation should be:

1.2 Data Sources

Data include total water use and sectoral water use, gross domestic product (GDP), and population for Xinjiang and its prefectures. Water use data for Xinjiang (1990–2020) were obtained from the Xinjiang Water Resources Bulletin, Xinjiang Statistical Yearbook, and related literature. Prefecture-level sectoral water use data were available from 2004 onward due to publication and statistical standards changes. GDP data (in constant 2000 prices) and population data were sourced from the Xinjiang Statistical Yearbook and national population census data. Benchmark data for northwestern China (Qinghai,### 1.3 Methods

1.3.1 Temporal Decomposition of Total Water Use We employed the LMDI method to analyze factors influencing temporal changes in Xinjiang' s water use from 1990–2020. Total water use includes production water (agriculture, industry, services), domestic water, and ecological water. The decomposition accounts for differences in driving mechanisms between production and domestic water use.

Total water use (wu) is the sum of sectoral water use:

$$wu = \sum_{k=1}^{5} wu_k$$

where wu_k represents water use in sector k (agriculture, industry, services, domestic, and ecological).

Production water use (wu_{prod}) is expressed as:

$$wu_{prod} = \sum_{k=1}^{3} wu_k = \sum_{k=1}^{3} wik \times GDP_k = \sum_{k=1}^{3} \alpha_k \times gdp \times pop$$

where wik is water use intensity of sector k (m^3 per yuan), α_k represents industrial structure (share of sector k in GDP), gdp is per capita GDP (yuan per person), and pop is total population (10^4 persons).

Domestic water use (wu_4) is expressed as:

$$wu_4 = wup_4 \times pop$$

where wup_4 is per capita domestic water use (m^3 per person).

The change in water use between periods t and $t+1$ (Δwu) is decomposed as:

$$\Delta wu = wu^{t+1} - wu^t = \Delta wu_I + \Delta wu_A + \Delta wu_{gdp} + \Delta wu_{pop} + \Delta wu_{dp} + \Delta wu_{eco}$$

where Δwu_I, Δwu_A, Δwu_{gdp}, Δwu_{pop}, Δwu_{dp}, and Δwu_{eco} represent changes due to water use intensity, industrial structure, per capita GDP, population, per capita domestic water use, and ecological water use, respectively.

Population change affects both production and domestic water use, so Δwu_{pop} is the sum of Δwu_{pop1} (production) and Δwu_{pop2} (domestic). Using the LMDI method, production water change is decomposed as:

$$\Delta wu_I = \sum_{k=1}^{3} \frac{wu_k^{t+1} - wu_k^t}{\ln(wu_k^{t+1}) - \ln(wu_k^t)} \ln\left(\frac{wik^{t+1}}{wik^t}\right)$$

$$\Delta wu_A = \sum_{k=1}^{3} \frac{wu_k^{t+1} - wu_k^t}{\ln(wu_k^{t+1}) - \ln(wu_k^t)} \ln\left(\frac{\alpha_k^{t+1}}{\alpha_k^t}\right)$$

$$\Delta wu_{gdp} = \sum_{k=1}^{3} \frac{wu_k^{t+1} - wu_k^t}{\ln(wu_k^{t+1}) - \ln(wu_k^t)} \ln\left(\frac{gdp^{t+1}}{gdp^t}\right)$$

$$\Delta wu_{pop1} = \sum_{k=1}^{3} \frac{wu_k^{t+1} - wu_k^t}{\ln(wu_k^{t+1}) - \ln(wu_k^t)} \ln\left(\frac{pop^{t+1}}{pop^t}\right)$$

Domestic water change is decomposed as:

$$\Delta wu_{dp} = \frac{wu_4^{t+1} - wu_4^t}{\ln(wu_4^{t+1}) - \ln(wu_4^t)} \ln\left(\frac{wup_4^{t+1}}{wup_4^t}\right)$$

$$\Delta wu_{pop2} = \frac{wu_4^{t+1} - wu_4^t}{\ln(wu_4^{t+1}) - \ln(wu_4^t)} \ln\left(\frac{pop^{t+1}}{pop^t}\right)$$

Ecological water change (Δwu_{eco}) is calculated directly as the difference between periods. This decomposition ensures no residual error, a feature validated in water resources research.

1.3.2 Spatial Decomposition of Per Capita Water Use To analyze why Xinjiang' s per capita water use exceeds northwestern China and national averages, we decompose the difference using spatial LMDI. Per capita water use (wup) is:

$$wup = \frac{wu}{pop} = \sum_{k=1}^{3} wik \times \alpha_k \times gdp + \sum_{k=4}^{5} wup_k$$

The difference between Xinjiang' s per capita water use (wup_{xj}) and the benchmark (wup_{bench}) is:

$$\Delta wup = wup_{xj} - wup_{bench} = \Delta wup_I + \Delta wup_A + \Delta wup_{gdp} + \Delta wup_{dp} + \Delta wup_{eco}$$

where each term represents the contribution of differences in water use intensity, industrial structure, per capita GDP, per capita domestic water use, and per capita ecological water use, respectively. The components are calculated using analogous LMDI formulas, with wk as the intermediate variable:

$$\Delta wup_I = \sum_{k=1}^{3} \frac{wup_k^{xj} - wup_k^{bench}}{\ln(wup_k^{xj}) - \ln(wup_k^{bench})} \ln\left(\frac{wik^{xj}}{wik^{bench}}\right)$$

$$\Delta wup_A = \sum_{k=1}^{3} \frac{wup_k^{xj} - wup_k^{bench}}{\ln(wup_k^{xj}) - \ln(wup_k^{bench})} \ln\left(\frac{\alpha_k^{xj}}{\alpha_k^{bench}}\right)$$

$$\Delta wup_{gdp} = \sum_{k=1}^{3} \frac{wup_k^{xj} - wup_k^{bench}}{\ln(wup_k^{xj}) - \ln(wup_k^{bench})} \ln\left(\frac{gdp^{xj}}{gdp^{bench}}\right)$$

The domestic and ecological water differences are calculated directly from per capita values. This spatial decomposition enables quantification of factors causing Xinjiang' s elevated per capita water use.

2. Results

2.1 Spatiotemporal Patterns of Water Use in Xinjiang

2.1.1 Temporal Trends Xinjiang's total water use showed a distinct inverted-U shape from 1990-2020 [Figure 2: see original paper]. Water demand grew continuously from the 1990s with socioeconomic development and population growth, peaking at 588.1$×10^{8}$ m^3 before declining. To alleviate mounting pressure, Xinjiang implemented total water use controls and promoted efficient irrigation, causing the subsequent decrease. Agriculture dominated water use, consistently accounting for over 90% of the total, though this share slowly declined with urbanization and industrialization. By 2020, the shares were: agriculture 90.9%, industry 2.0%, services 1.3%, domestic 2.7%, and ecological 3.1%.

Per capita water use exhibited a declining trend, dropping from 3002.8 m^3 in 1990 to 2188.4 m^3 in 2020, though still far exceeding the national average of 411.7 m^3. The trend can be divided into three phases: (1) 1990-1995: rapid decline as population growth outpaced water use growth; (2) 1995-2015: relative stability, fluctuating between 2380.0-2599.1 m^3; and (3) post-2015: rapid decline due to total water use reduction.

2.1.2 Spatial Distribution Based on available data, we analyzed spatial patterns using 2004 and 2020 data [Figure 3: see original paper]. Total and per capita water use showed marked spatial heterogeneity, with higher values concentrated in the water-rich Tarim River, Ili River, and Irtysh River basins. Except for Urumqi, all prefectures exceeded northwestern China (379.7 m^3) and national (411.7 m^3) averages. From 2004-2020, 11 prefectures increased total water use, while 3 (Shihezi, Altay, Hami) decreased. Per capita water use declined in 10 prefectures but increased in 4 (Tacheng, Kizilsu, Bortala, Changji).

Agriculture remained the primary water user. In 2020, all prefectures except Urumqi, Karamay, Shihezi, and Hami had agricultural water use shares exceeding 80%, with the highest shares in western Xinjiang. Industrial water use shares were generally below 5%, with some prefectures below 1%. Service and domestic water use shares were low, ranging 0.0-2.1% and 0.9-21.4% respectively in 2020, both showing increases from 2004. Ecological water use varied widely (0.8-28.6%), with Karamay having the highest share.

2.2 Factor Decomposition Analysis

2.2.1 Temporal Decomposition of Total Water Use LMDI decomposition reveals varying contributions of different factors [Figure 4: see original paper]. Water use intensity and industrial structure consistently exerted negative effects on total water use, while per capita GDP and population had persistent positive effects. Per capita domestic water use and ecological water use showed fluctuating effects.

The absolute effects of water intensity and industrial structure were largest. As population growth slowed, its contribution to water use growth gradually decreased. Per capita domestic water use had relatively small effects across all periods. Ecological water use was not statistically included before 2003, so it did not affect water use changes during 1990-2003; thereafter, its effect became positive.

Cumulative effects from 1990-2020 show that per capita GDP and population growth were the main drivers of water use increase, contributing +1062.3$\times10^{8}$ m^3 and +250.6$\times10^{8}$ m^3 respectively (1120.6% and

264.4% contribution rates). Water intensity reduction and industrial structure transformation were the primary inhibitors, contributing -833.4$×10^{8}$ m^3 and -414.4$×10^{8}$ m^3 (-437.1% and -879.1% rates). Per capita domestic and ecological water changes contributed only +8.7$×10^{8}$ m^3 and +20.9$×10^{8}$ m^3 (22.0% and 9.3% rates).

2.2.2 Spatial Decomposition: Xinjiang vs. Benchmarks Xinjiang' s per capita water use significantly exceeds northwestern China and national averages. Spatial LMDI decomposition identifies the main causes .

Compared with northwestern China, water intensity and industrial structure differences are the primary reasons for Xinjiang' s higher per capita water use, with contributions expanding over time. In 2020, these factors contributed 1383.2 m^3 (64.1% contribution rate) and 525.5 m^3 (24.4% rate) respectively. Xinjiang' s water intensity was 3.2 times the northwestern average, and its agricultural-dominated structure (14.4:34.4:51.3 for primary:secondary:tertiary sectors) was less favorable for water conservation than northwestern China' s 7.7:37.8:54.5 structure. Per capita GDP differences contributed 325.6 m^3 (15.1% rate), while per capita domestic and ecological water differences had minimal impact.

Compared with the national average, water intensity, industrial structure, and per capita ecological water differences were the main factors. In 2020, water intensity contributed 1425.7 m^3 (76.5% rate) and industrial structure contributed 2617.8 m^3, though the latter had a negative contribution rate (-12.6%) because Xinjiang' s lower per capita GDP (slightly above northwestern China but below national average) had a water-saving effect. Per capita domestic and ecological water differences contributed minimally.

2.2.3 Spatial Decomposition Within Xinjiang Large spatial heterogeneity in water intensity across prefectures is a major cause of per capita water use differences. Using 2004 and 2020 data, we decomposed differences between each prefecture and the Xinjiang average .

In 2020, 11 prefectures had water intensity above the Xinjiang average, contributing up to 2268.9 m^3 to per capita water use differences. High-intensity prefectures were mainly in the Tarim River upper reaches, Ili River basin, and Irtysh River basin, while low-intensity areas were concentrated in the northern Tianshan slope, Turpan-Hami basin, and eastern Tarim Basin.

Industrial structure differences also significantly contributed to spatial heterogeneity. In 2020, 10 prefectures had agricultural shares 16.1–40.2% above the Xinjiang average, increasing per capita water use by up to 1793.6 m^3. These prefectures were mainly in southwestern and northeastern Xinjiang. The remaining 4 prefectures (Karamay, Urumqi, Shihezi, Hami) had agricultural shares 0.8-10.6% below average, reducing per capita water use.

Per capita GDP differences were another important factor. In 2020, 7 prefectures had per capita GDP above the Xinjiang average (mainly in the northern Tianshan region), contributing up to 2182.6 m^3 to differences. The 7 prefectures below average were primarily in southern Xinjiang (Hotan, Kashgar, Kizilsu, Aksu) and northern Xinjiang (Ili Prefecture, Altay) plus eastern Turpan.

Per capita domestic and ecological water use differences had relatively small contributions. In 2020, 8 prefectures had higher per capita domestic water use, contributing -24.3 to +17.4 m^3 to differences. Nine prefectures had higher per capita ecological water use, contributing -67.6 to +210.6 m^3.

Overall, water intensity, per capita GDP, and industrial structure differences are the main causes of spatial variation in per capita water use across Xinjiang, while domestic and ecological water differences have minor impacts. The spatial differences in these factors gradually narrowed from 2004–2020, leading to reduced spatial heterogeneity in per capita water use.

3. Discussion

Our findings align with previous studies: economic growth and population increase drive water use growth, while intensity reduction and structural change inhibit it. Compared with Wu et al. and Zhang et al., our study covers a longer period (1990–2020), incorporates production, domestic, and ecological water use, and employs spatial LMDI to analyze both internal Xinjiang differences and comparisons with external benchmarks, providing deeper insights for policy.

Despite recent declines in total water use, high water intensity and structural imbalances persist across Xinjiang, with per capita water use remaining far above national and regional averages, creating acute supply-demand conflicts in some prefectures. We recommend:

1. **Strict control in high-intensity regions**: For areas with high water development intensity and use intensity (e.g., Aksa, Kashgar, Shihezi), enforce total quantity and efficiency control targets to reduce impacts on natural water systems.
2. **Agricultural structure adjustment**: For agriculture-dominated regions (e.g., Aksa, Bortala, Altay), rationally plan planting scales based on water availability, reduce high-water-consumption crops, expand water-saving irrigation, and accelerate economic and water use structural transformation while ensuring food security.
3. **Optimized allocation**: For water-scarce but economically important areas like the northern Tianshan Economic Belt, advance water network construction to optimize spatial allocation and maximize socioeconomic and ecological benefits.

4. Conclusions

This study analyzed spatiotemporal evolutionary patterns and influencing factors of water use in Xinjiang from 1990–2020 using the LMDI method. The main conclusions are:

1. **Temporal trends**: Total water use followed an inverted-U trajectory (446.8–588.1$×10^{8}$ m^3), while per capita water use declined from 3002.8 m^3 to 2188.4 m^3, still far exceeding the national average. Agriculture dominated water use, consistently accounting for over 90%.

2. **Driving factors**: Water intensity reduction and industrial structure upgrading were the main reasons for total water use decline, contributing -833.4$×10^{8}$ m^3 and -414.4$×10^{8}$ m^3 respectively. Per capita GDP and population growth were the primary drivers of increase, contributing +1062.3$×10^{8}$ m^3 and +250.6$×10^{8}$ m^3. Domestic and ecological water changes had minor effects.

3. **Benchmark comparisons**: High water intensity and agriculture-dominated structure were the main reasons Xinjiang' s per capita water use far exceeded northwestern China and national averages. In 2020, water intensity differences contributed 1383.2 m^3 vs. northwestern China and 1425.7 m^3 vs. national average; industrial structure differences contributed 525.5 m^3 and 2617.8 m^3 respectively.

4. **Spatial heterogeneity**: Water intensity, per capita GDP, and industrial structure differences were the main causes of spatial variation in per capita water use within Xinjiang, creating differences up to 2268.9 m^3, 2617.8 m^3, and 2182.6 m^3 between prefectures and the regional average. Domestic and ecological water differences had minimal impact.

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Note: Figure translations are in progress. See original paper for figures.