

Original Research

Quality Assessment and Spatial Distribution of Human Settlements in Western China: The Case of 12 Provinces, Municipalities and Autonomous Regions

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Abstract

To improve the unbalanced development in the western region, it is necessary to explore the construction level of the human settlement. Regarding social well-being, this paper uses data spanning the period from 2015 to 2020 and develops a system of indicators to assess human settlements in western China along five dimensions: Health and Safety, Social Development, Economic Conditions, Environmental Health, and Working Conditions. The study concludes that, firstly, Yunnan possesses the highest human settlement quality index with a relative proximity of 0.478, while Qinghai has the lowest, with a human settlement quality index of 0.209. Secondly, concerning temporal dimensions, the spatial distribution pattern of human settlement quality in western China generally exhibits a southeast high and northwest low pattern. In addition, coordinated, stable, and sustainable development is crucial to maintaining the advantage of human settlement quality. Thirdly, there is not necessarily a positive correlation between economic development and human settlement quality. Therefore, in terms of distribution types, Sichuan and Inner Mongolia belong to the “high human settlement quality-high economic level” type, whereas Shaanxi, Chongqing, Xinjiang, and Ningxia belong to the “low human settlement quality-high economic level” type. Yunnan, Gansu, and Guangxi are in the “high human settlement quality-low economic level” category, while Guizhou, Tibet, and Qinghai belong to the “low human settlement quality-low economic level” category.

Keywords: Western China, human settlement, entropy method-TOPSIS, gray-scale correlation analysis

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Introduction

The gradual advance of modern industrial civilization and the gradual penetration of economic globalization have, on the one hand, intensified the imbalance between urban and rural development [1] and, on the other hand, triggered a series of land development and utilization problems, as well as ecological and environmental problems [2-4]. As a development path to maintain a harmonious and healthy environment, build a shared coexistence for all, and reflect a sustainable society, the ecological transformation of economic development is an inevitable choice for modern industrial civilization to overcome the development dilemma [5, 6].

In 2022, the Communist Party of China (CPC) proposed to follow the modern development path of “modernization in which people and nature live in harmony”. The CPC proposed that development should be planned from the perspective of respecting, responding to, and protecting nature [7]. This suggests that in future societal development, environmental and economic values are equally important, two inseparable sides [8]. Especially in the context of the comprehensive construction of socialist modernization, the comprehensive construction of a well-off society strategy, the rural revitalization strategy, and the sustainable development strategy, the construction of human settlements must meet higher standards and requirements. As China’s economy enters a new stage of development, questions arise on how to effectively transform economic value into social value through habitat construction, how to correctly evaluate the level of human settlements in the region, improve people’s living conditions through human settlements, and encourage the establishment of new development concepts of innovation, coordination, ecology, openness, and cooperation, which have gradually developed into suggestions for solving regional human settlement problems, a new development concept.

This paper examines the hierarchical and spatial distribution patterns of the human environment in western China from the perspective of social welfare, fully assesses the human environment situation in western China and its relationship with the influencing factors, and provides scientific guidance and reference for Chinese policymakers in the construction of the human environment and territorial spatial planning. The research in this paper is intended to provide a reference for the research and development of the human environment in this new situation.

Research Overview

The science of habitat originated from the science of human settlement in the 1950s [9, 10]. It refers to the fields and spaces in which people live and work and is closely related to architecture, landscape architecture, and planning. With the deepening of research,

the habitat has become an increasingly important topic for interdisciplinary discussion and research. Because it involves the scope of architecture, planning, geography, and the environment, Chinese scholars have divided the science of habitat into five categories: natural systems, human systems, social systems, housing systems, and support network systems [11].

In the existing international research, the two main research directions are Habitat Impact Assessment and Habitat Environment Database Establishment [12, 13]. Human settlement evaluation systems such as LEED standards and Eco-Quantum standards have also been developed up to now [14-16]. Sun et al. created a quantitative model for assessing the quality of human habitation in residential communities. The results show strong consistency over the years [17].

The study of habitat environments in China has started since the 1980s [18]. With the introduction of the scientific concepts of development, harmonious society, and rural revitalization strategy, the science of habitat environment has recently begun to receive high attention from Chinese governments at all levels [19, 20]. At the same time, Chinese scholars have also started to conduct relevant studies from different methods and perspectives. Zhou et al. conducted a study on satisfaction with the human environment in urban areas of Beijing through a questionnaire survey [21]. Yan et al. investigated the regional differences in Chinese settlements and analyzed their spatial effects. Dai et al. worked on assessing human impacts on rural settlements and identifying dynamic patterns [22].

Through continuous practice, although the science of habitat and related research has made a series of great achievements. However, there are problems and shortcomings in the rapid construction of ecological civilization in contemporary China. Firstly, and most crucially, the use of empirical methods to reveal the evolutionary path of habitat development and its performance assessment mechanism is still in its infancy, and more scientific and rational assessment methods need to be further explored. In addition, the dual model of urban-rural social development has exacerbated the problem of unbalanced and inadequate urban-rural life and urban-rural development. There are few researchers studying the quality of human settlements in marginal areas.

This study establishes a scientific and quantitative measurement index system to determine the quality of the habitat environment in western China and its spatial and temporal changes through entropy-weight-TPOPSIS and gray-scale correlation analysis. It provides a reference plan for the construction and planning of human settlements in the west during the period of socialist modernization and aims to improve people’s sense of well-being. Ultimately, it will provide a reference and help to improve the habitat environment and achieve a better life in western China.

Study Area and Research Method

Western China

The study area is western China. The complete area of western China is about 6,781,589,000 rectangular kilometers, accounting for about 70.6% of the total area of China. At the same time, western China has distinct cultural characteristics, regional flavors, and numerous ethnic groups. The northwestern region is vast and boundless, forming the Western cultural sphere. Meanwhile, the expansive spatial environment and rich resource conditions in western China give western China significant development potential (Fig. 1).

It is worth noting that the special environment of the vast territory, inaccessibility, and relatively sparse and scattered population in western China has created a state of small-scale and fragmented cultural development. The relative isolation and fragmentation of the region have constrained the overall development of western ethnic culture. With the exception of the Sichuan Basin and the Guan Zhong Plain, the vast majority of western China is relatively economically backward. The living standard of the population is very different

from that of central and eastern China. The uneven and disproportionate development that has taken place up to this point has resulted in an uneven and underdeveloped western China, more so than in central and south-central China. At the same time, West China's ecological footprint has also been partially destroyed. According to a recent study, the ecological footprint of the entire population of western China is 162.5 x 104 km². This indicates that the intensity of production and livelihood activities in western China exceeds its ecological carrying capacity. The regional ecosystems in western China are under excessive human exploitation and pressure [23]. The report shows that the overall level of development and human settlement in western China are relatively backward, with many complex and intractable problems affecting people's lives, and that uneven and inadequate improvements are the main issues constraining such development in China.

In order to analyze these issues in depth and to identify and improve the level of human settlement and living conditions in Western China, this study examines the level and spatial distribution of human settlement.

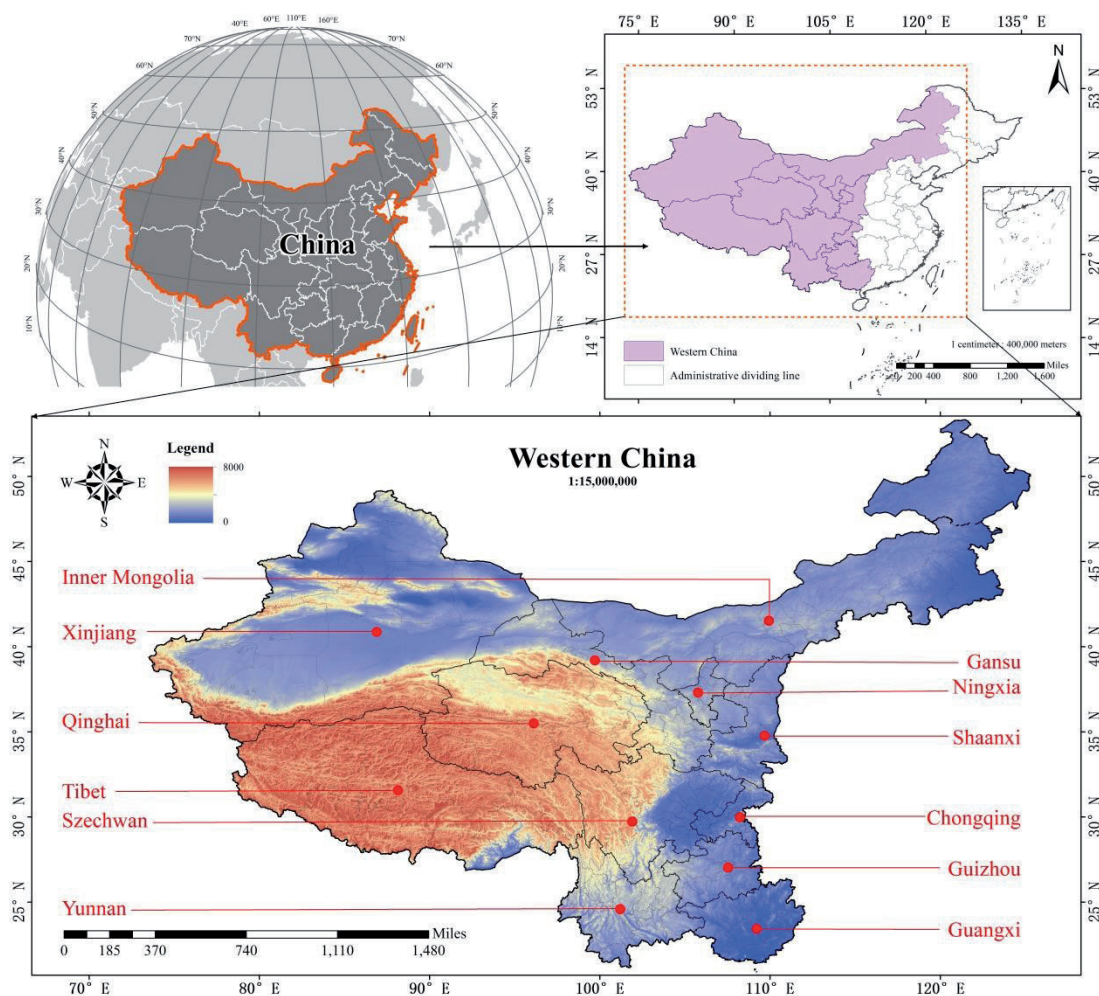


Fig. 1. Location map of Western China.

Research Methodology

The complete comparison method using gray correlation evaluation combined with the TOPSIS method takes full account of the uncertainty of the evaluation indicators while also taking into account objectivity and addressing the shortcomings of the low credibility of the quantitative gray correlation mode. On this basis, the research framework of this paper is constructed (Fig. 2).

Entropy Weight Method-TOPSIS Evaluation Model

According to the entropy concept of the TOPSIS assessment model, the assessment process consists of two phases. The phases are as follows: In the first phase, the entropy value of each key indicator in the indicator system is determined and estimated. In the second step, based on the dimensionless raw data matrix, the optimal and inferior solutions among the finite solutions were identified. The relative worthiness is then evaluated based on the relative distance between the best or worst answers [24].

Grayscale Correlation Analysis Method

This study also uses gray correlation analysis to analyze the relationship between the overall level of human settlement quality in each region and the

impact of various assessment indicators (Fig. 2). Gray correlation assessment can be used to describe and quantify the relationships in the design of the system. It determines the data correlation between objects by assessing the similarity of the geometric models of the data. This gray correlation between the geometric models, i.e., the human settlement quality index of the western provinces of China, is influenced by their evaluation indicators. The decision-making principle of gray correlation analysis is well complemented by the TOPSIS entropy method. Chen Zhi Xia et al. combined TOPSIS and the gray correlation analysis method to construct a comprehensive evaluation model of the happiness index. From the study, it can be seen that this comprehensive research method can effectively avoid the subjectivity of questionnaire measurement and has good application prospects [25]. Lin, SJ, and Hou, LD assessed the environmental sustainability of 11 rural human settlements in Zhejiang Province based on the entropy weight method, TOPSIS, and gray correlation analysis. It can be seen that the use of TOPSIS and gray correlation analysis can provide efficient assessment methods and referable opinions for the construction of human settlements [26]. Yang, Q. et al. assessed the quality of human settlements in MSBBC from 2000 to 2020 through the entropy weighting method TOPSIS and the gray relational degree model. The results conclude that the method not only provides a strong reference for creating livable environments and promoting regional

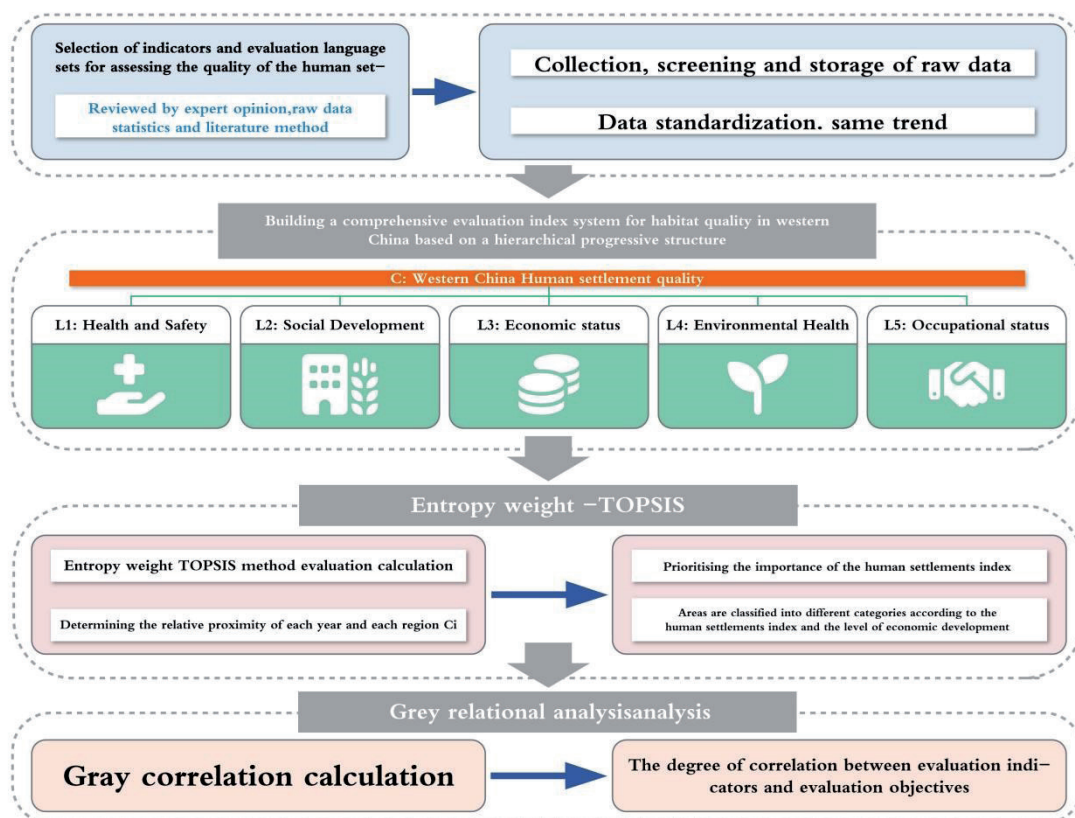


Fig. 2. Flowchart of the Framework of the Study on the Happiness Index of Residents in Western China.

sustainability, but also helps to address challenges such as environmental pollution and climate change [27]. Some scholars have also used the entropy weighting method TOPSIS and the gray relational analysis method for assessing the implementation potential of housing prefabrication and the resilience of the integrated system of soil and water resources, etc., which demonstrated the good applicability of the combination of these two methods [28-30].

Rating Indicator System and Data Calculation

Principles for Establishing the Human Settlement Quality Index System

Human-Centered Principle

This principle posits that people's happiness is the purpose, driving force, and test standard of scientific development. The human settlement quality index system requires constant adherence to the guiding ideology of "human-oriented", which emphasizes the achievement of comprehensive social development on the basis of economic development.

The Principle of Truthfulness

Indicators must truly reflect the living conditions of people on the ground. This includes a range of real data on people's income status, employment status, income distribution, urban and rural quality, etc.

Principle of Comprehensiveness

It is important to take full account of international standards and national conditions and to strive for a unity of content and structure. Comprehensiveness requires the construction of indicators that cover as many elements as possible that are relevant to the public.

Attention must be paid to the hierarchical requirements to ensure a comprehensive assessment of the level of well-being of the population in a holistic and multi-faceted manner. In addition, the precept of comprehensiveness is additionally reflected in the building of the index machine with both goal and subjective indicators. By introducing some crucial subjective indications, people are allowed to qualitatively assess some symptoms that are challenging to measure with goal indicators.

Operability Principle

Accessibility and assessment power must be considered. Factors to be considered include the availability of records for the indicators, the degree of placement of the indicators, the dimensional techniques of the indicators, and the scale environment

of the indicators. Indicators should be simple, easy to understand, and easy to operate.

Principles of Comparability and Independence

The principle of comparability is expressed in terms of longitudinal comparability. Evaluation results can be compared in a structured way, which provides useful insight into levels and trends in social services in different contexts and settings. For this reason, the indicator system has at least three levels: target level, measurement level, and indicator level. Independence means that indicators at one level are not exhaustively linked and cannot be substituted.

Comprehensive Evaluation Indicator System for Habitat Quality in Western China

There are many factors that can influence the evaluation objectives. Therefore, the evaluation indicator system uses a modern tiered model. In establishing the benchmark, input from relevant experts and designers is gathered to complement and confirm the elements of the rating index.

Overall Indicator: i.e., the overall indicator of the Habitat Quality Index for the western region under the stratified progressive model.

Since the construction of human settlements is closely related to human development and well-being [31, 32], this paper draws on the relevant studies on the evaluation of the human development index to construct dimensional indicators [33, 34]. Dimensional Indicators (Level 1 Indicators): indicators used to further specify the overall index. This consists of five Level 1 indicators, L1-L5, as described below:

L1 Health and Safety: This is a concept that encompasses the health status of individuals and communities, including activities that prevent disease, extend life expectancy, and promote physical and mental health. Health safety also encompasses measures to prevent workplace injuries and illnesses, as well as strategies for responding to public health emergencies.

L2 Social Development: This is a concept that encompasses social progress and improvement, including aspects such as education, health, human rights, democracy, economic growth, equality, and cultural diversity. The goal of social development is to improve the quality of life of people in human settlements, reduce poverty, improve education and health, protect the environment, and promote equitable and inclusive societies.

L3 Economic Status: This is a concept that describes the economic health of an individual, household, community, or nation and includes factors such as income, employment, prices, inflation, and economic growth. Economic status can influence the quality of habitat and, thus, the quality of life of people, including their housing, education, health status, and the leisure activities they are able to enjoy.

L4 Environmental Health: This is a concept that encompasses environmental protection and improvement, including aspects of air and water quality, waste management, pollution control, and biodiversity conservation. Environmental health is closely related to the quality of human settlements and aims to protect human health, maintain the health of ecosystems, and conserve the earth's natural resources.

L5 Occupational Status: This is a concept that describes the employment and work situation of an individual or community, including factors such as employment rates, unemployment rates, job satisfaction, work environment, and opportunities for career development. Occupational status can affect people's income, their quality of life, and their status in society.

Sub-indicators (Level 2 indicators): the main indicators are broken down in detail by structural elements. A total of 34 secondary indicators (X1-X34) were screened for induction. These elements have been used to create an integrated system of indicators of the

quality of settlements in the Western region (Table 1).

Data Sources and Processing Methods

The data in this paper are sourced from the statistical yearbooks of various regions in western China. Due to data availability and the scope of this study. This study adopts a 6-year assessment period, spanning from 2015 to 2020. Both the mean growth rate method and the interpolation method were used to obtain the missing data.

Comprehensive Evaluation of TOPSIS Entropy Weight Method and Gray Relational Analysis

Entropy Method-TOPSIS Calculation

To begin, import the data into the same targeting formula. Let H_{ij} represent the i th initial data for the j th indicator to be evaluated. Next, normalize the

Table 1. Integrated Human Settlement Quality Evaluation Index System for Western China.

Total index	Dimensional Indicators	Sub-indicators	Unit	Indicator Type	Entropy power
C: Western China Human settlement quality C: Western China Human settlement quality	L1: Health and Safety	X1: Life expectancy per capita	age	+	0.0184
		X2: Total number of traffic accidents per 10,000 people	From 10,000 people	–	0.0223
		X3: Number of hospital beds per 10,000 people	Beds per 10,000 people	+	0.0345
		X4: Number of health technicians per 10,000 population	Position / 10,000 people	+	0.0509
	L2: Social Development	X5: The ratio of investment in science, education, culture, health, and sports to financial expenditure	%	+	0.0232
		X6: The proportion of full-caliber social security expenditure to fiscal expenditure	%	+	0.0236
		X7: Urban Road area per capita	m ²	+	0.0331
		X8: Passenger traffic	10,000 people	+	0.0364
		X9: Number of buses per 10,000 people	million people/volume	+	0.0827
		X10: Vehicle ownership per 10,000 people	million people/volume	+	0.0266
		X11: Public library collection ownership per capita	Person/book	+	0.0277
		X12: Combined population coverage of TV programs	%	+	0.0137
		X13: Integrated population coverage of radio programs	%	+	0.0101
		X14: Divorce rate	%	–	0.0176
		X15: Number of scientific and technological personnel per 10,000 people	Position/10,000 people	+	0.0455
		The X16: School-age children enrollment rate	%	+	0.0168
		X17: Number of full-time teachers per 10,000 people	Position/10,000 people	+	0.0422
		X18: Number of schools per 10,000 people	House/10,000 people	+	0.0648

Table 1. Continued.

C: Western China Human settlement quality	L3: Economic Status	X19: GDP per capita	Yuan	+	0.0209
		X20: Disposable income per capita	Yuan	+	0.0279
		X21: Food production per capita	kg/person	–	0.0374
		X22: Income ratio between urban and rural residents	%	–	0.0181
		X23: Per capita consumption expenditure/per capita disposable income of urban residents	%	–	0.0351
		X24: Consumer Price index	/	–	0.0277
		X25: Commodity retail price index	/	–	0.019
		X26: Housing area per capita	m ²	+	0.0338
		X27: Resident Engel coefficient	%	–	0.0188
	L4: Environmental Health	X28: Forest cover	%	+	0.0369
		X29: Public green space per capita	m ²	+	0.0228
		X30: Greening coverage of built-up areas	%	+	0.0152
		X31: Centralized sewage treatment rate	%	+	0.009
		X32: Harmless treatment rate of urban domestic waste	%	+	0.0164
	L5: Occupational Status	X33: Urban registered unemployment rate	%	–	0.0351
		X34: Average wage of employees on duty	Yuan	+	0.0359
		X34: Average wage of employees on duty	Yuan	+	0.0359

measurements using two formulas: (1) the negative dimension normalization formula and (2) the average measurement normalization formula.

$$H'_{ij} = \frac{H_{\max} - H_{ij}}{H_{\max} - H_{\min}}, \quad (1)$$

$$H'_{ij} = 1 - \frac{|H_{ij} - H_{\max}|}{M} \quad M = \max\{|H_{ij} - H_{\max}|\}, \quad (2)$$

The second step further imports the data into a weighted normalization matrix. We can construct an evaluation table where Z_{ij} is the normalized value of the j th indicator at the i th evaluation point.

$$\vartheta = \begin{Bmatrix} Z_{11} & Z_{12} & \cdots & Z_{1j} \\ Z_{21} & Z_{22} & \cdots & Z_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ Z_{i1} & Z_{i2} & \cdots & Z_{ij} \end{Bmatrix} = (Z_{ij})_{mn} \quad Z_{ij} = \frac{H'_{ij}}{\sqrt{\sum_{j=1}^n (H'_{ij})^2}}, \quad (3)$$

The third step is to calculate the pure distance D between each index and the optimal vector and inferior vector according to the formula (4,5) and combine it with the entropy weight.

$$D_i^+ = \sqrt{\sum_{j=1}^m \omega_j (Z_j^{\max} - Z_{ij})^2}, \quad (1 \leq i \leq m) \quad (4)$$

$$D_i^- = \sqrt{\sum_{j=1}^m \omega_j (Z_j^{\min} - Z_{ij})^2}, \quad (1 \leq i \leq m), \quad (5)$$

where ω refers to the entropy weight value. In the fourth step, the relative approximation value C_i (human settlement quality index) is determined, i.e., how close each reference point is to the best response (6).

$$C_i = \frac{D_i^{\min}}{D_i^{\max} + D_i^{\min}}, \quad (1 \leq i \leq m), \quad (6)$$

The solutions are sorted according to the value of $C_i (i \in m)$, the closer the value of C_i is to the positive ideal solution, the better the solution (Table 2).

Grayscale Correlation Analysis

The feature set and parent set are determined according to the purpose of the assessment. A feature series is a collection of information on the factors that influence the overall quality of life indicators of residents in a local comprehensive human settlement quality index system in western China. If the feature series X'_i with m being the number of indicators, then n feature series X'_i forms the following table:

$$X'_i = (X_i(1), X_i(2), \dots, X_i(m))^T, \quad (i = 1, 2, \dots, n),$$

Table 2. Relative proximity values C_i by provinces in western China.

Province	2015	2016	2017	2018	2019	2020	Synthesis	Ranking
Gansu	0.45	0.487	0.411	0.369	0.362	0.241	0.434	3
Guangxi	0.366	0.386	0.263	0.427	0.384	0.269	0.405	4
Guizhou	0.32	0.346	0.230	0.428	0.392	0.255	0.380	8
Inner Mongolia	0.409	0.392	0.244	0.402	0.407	0.258	0.404	5
Ningxia	0.303	0.277	0.179	0.297	0.321	0.211	0.314	10
Qinghai	0.209	0.188	0.119	0.197	0.214	0.143	0.209	12
Shaanxi	0.359	0.371	0.233	0.410	0.381	0.251	0.389	6
Szechwan	0.418	0.415	0.255	0.472	0.492	0.295	0.441	2
Tibet	0.317	0.284	0.184	0.293	0.313	0.190	0.297	11
Xinjiang	0.3	0.306	0.193	0.340	0.341	0.580	0.342	9
Yunnan	0.405	0.414	0.277	0.519	0.509	0.370	0.478	1
Chongqing	0.391	0.364	0.545	0.397	0.384	0.252	0.385	7

The parent series is a comprehensive set of indicators describing the human settlement quality index in western China. If the parent series is X_0' , then there is a set of data that forms the main series.

$$X_0' = (X_0'(1), X_0'(2), \dots, X_0'(m))^T,$$

The exponential statistics are dimensionless. The dimensionless strategy includes the proposed charge method, preliminary charge method, and normalized transformation. Since the human settlement quality index of the western population is determined by a variety of influencing factors and will not increase with age, the average method is used to reduce the index data and establish a formula. Yes (7).

$$X_i(j) = \frac{X_i(j)}{\bar{X}_i}, \quad (7)$$

The index data dimension is complete. After the dimensionless statistical processing is completed, the absolute value of the difference between the ranking of each indicator and the corresponding factor in the matrix is recalculated.

Assuming that the absolute value of the rank difference between the index and the matrix table is Δ_i , the calculation result is formula (8).

$$\Delta_{ij} = |X_0(j) - X_i(j)| \quad (8)$$

As in equations (10, 11), the absolute value of the difference between each rating element and the attribute set of the corresponding element in the parent table is calculated as Δ_i to determine the minimum two-level difference $\Delta_i \min$ and the maximum two-level difference $\Delta_i \max$.

$$\Delta_i \min = \min_i \min_j |X_0(j) - X_i(j)|, \quad (9)$$

$$\Delta_i \max = \max_i \max_j |X_0(j) - X_i(j)| \quad (10)$$

To calculate the correlation coefficient between each attribute and the corresponding factor in the classification table, which is $\Delta_i \min$ for the two levels with the smallest difference and $\Delta_i \max$ for the two levels with the largest difference. Finally, calculate the weighted common denominator of each feature and the corresponding correlation coefficient. See formulas (11, 12) for the calculation method.

$$\partial_i(j) = \frac{\Delta_i \min - \rho \Delta_i \max}{\Delta_i j + \rho \Delta_i \max} \quad (11)$$

$$R_{0i} = \frac{1}{m} \sum_{j=1}^m \omega_j \partial_i(j), \quad (i = 0, 1, \dots, n; j = 1, 2, \dots, m.) \quad (12)$$

where ρ is the resolution factor, which takes values in the range (0,1). The equation ω_j is the weight of each indicator.

Statistical Analysis

Cross-Sectional Comparison between Different Provinces

In this study, the relatively close value of C_i represents the human settlement quality index. Estimates are then made by comparing the relatively close C_i values in different regions. According to the relative proximity ranking of each region, Yunnan

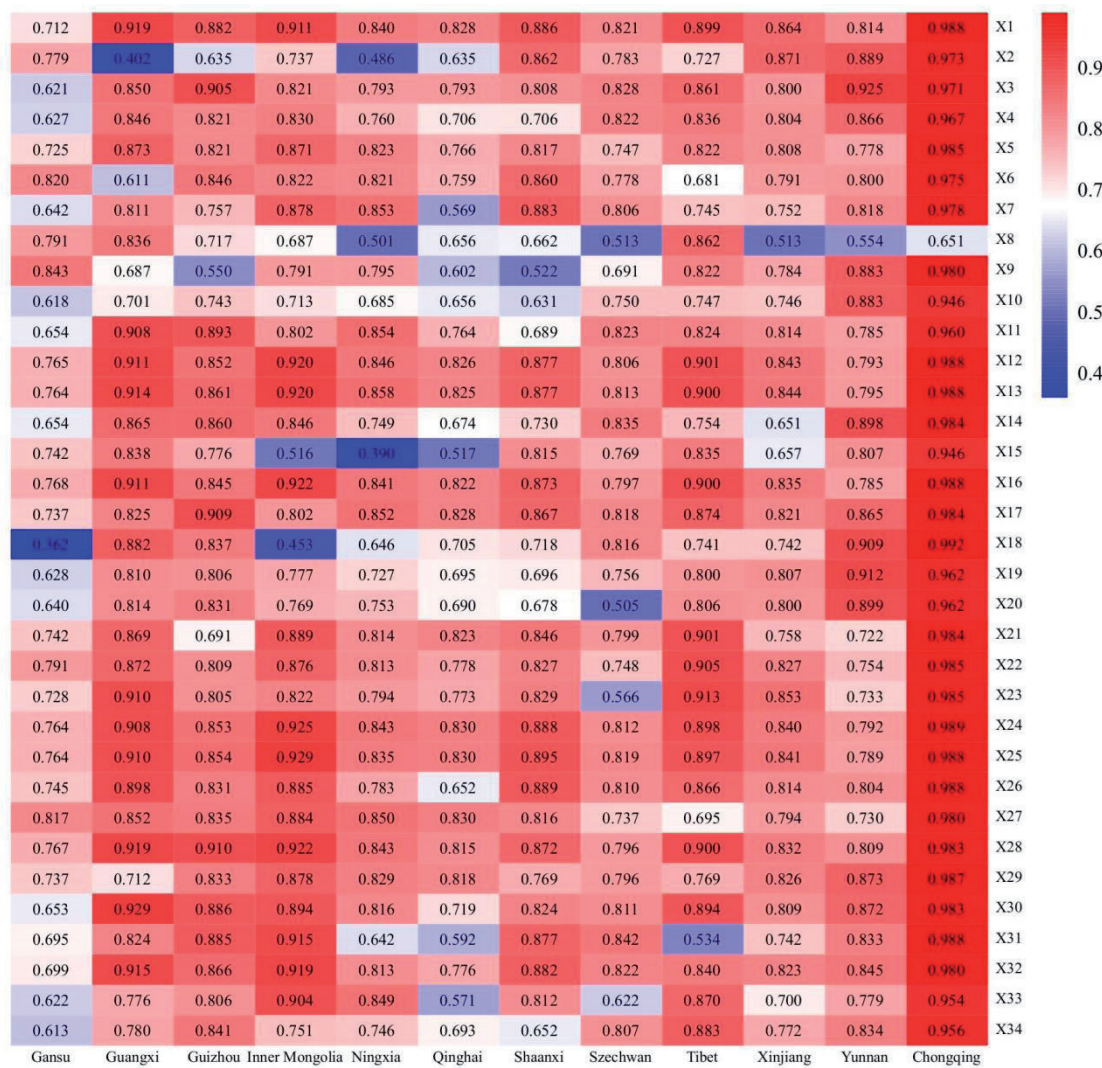


Fig. 3. Thermal correlation chart of the gray correlation analysis degree of sub-indexes in western China.

has the highest composite environmental ecological index, followed by Sichuan and Gansu in third place, with relative proximity C_i of 0.478, 0.441, and 0.434, respectively. This means that these three regions have the highest composite environmental ecological index in western China. Six regions, Guangxi, Inner Mongolia, Shaanxi, Chongqing, Guizhou, and Xinjiang, have a composite environmental ecological index for residents ranging from 4 to 9. This indicates that the level of social and public services in these six regions is relatively low and needs to be improved. Four regions, Xinjiang, Ningxia, Tibet, and Qinghai, have the lowest relative proximity values: C_i , 0.342, 0.314, 0.297, and 0.209, respectively. This indicates that these four regions have the lowest human settlement quality indexing in western China and need to focus on improving the integrated environmental ecosystem in these four regions (Table 2).

Each province in western China has a different level of economic development and a different regional location. The evaluation results show that the scale and level of economic development in the study area

have no significant impact on the regional human settlement quality index. Chongqing, with a GDP per capita of 78,200 RMB, has a very low ranking in the human settlement quality index. Gansu, with a GDP per capita of only 19,000 yuan, ranks third in the human settlement quality index score. In general, GDP per capita indicates the standard of living and economic development of a region, which indirectly reflects the human settlement quality index of the region. However, the results of this study indicate that the level of economic development does not have a significant effect on the composite environmental ecological index. Or, economic development does not necessarily have a positive relationship with human settlement quality.

Type Analysis of Different Regions

This study summarizes and analyzes the human settlement quality index (relative proximity C_i) of each region in western China by sampling the spatial distribution of the human settlement quality index in western China. This study classifies the integrated

environmental and ecological status of each region in western China.

Song Ying et al. classified the evaluated cities into three types based only on the happiness index and the scale of economic development. Specifically, they are the high happiness-low economic scale, the low happiness-high economic scale, and the low happiness-low economic scale [35]. Inspired by this, this paper combines the results of the TOPSIS entropy method with the human settlement quality index and the regional economic level of different regions in western China to classify the social and public service conditions in western China into four different types. Specifically, there are four types: high human settlements quality-high economic level, high human settlements quality-low economic level, low human settlements quality-high economic level, and low human settlements quality-low economic level. The classification is based on the human settlement quality index C_i and GDP per capita derived in this paper. The criteria for classification are: relative affinity value $C_i \geq 0.4$, which corresponds to a high comprehensive environmental-ecological level; and GDP per capita $\geq 45,000$, which corresponds to high human settlement quality.

Accordingly, western China is divided into four quadrants on the map (Fig. 4). Combined with the GDP per capita of each region, the regions in western China are classified as follows: Sichuan and Inner Mongolia can be classified in the “high human settlement quality-high economic level” category.

Shaanxi, Chongqing, Xinjiang, and Ningxia fall into the “low human settlement quality-high economic level” category; Yunnan, Gansu, and Guangxi fall into the “high human settlement quality-low economic level” category. Guizhou, the Tibet Autonomous Region, and Qinghai fall into the “low human settlement quality-low economic level” category (Fig. 4).

Longitudinal Comparison between Different Years

From 2015 to 2020, the human settlement quality index in different regions of western China ranged from 0.2 to 0.6, with the overall spatial pattern being the Upper Southeast, and Lower Northwest (Fig. 5 and Fig. 6).

Specifically, the provinces with the highest representation in the first ranking are Gansu and Yunnan, respectively. In 2015, 2016, and 2017, Gansu held the first rank in relative proximity, specifically 0.45, 0.487, and 0.484. This indicates that from 2015 to 2017, the residents of Gansu had the highest Human settlement quality index relative to the rest of Western China as a whole. In 2018, 2019, and 2020, Yunnan ranks first in relative proximity, with specific relative proximity C_i values of 0.519, 0.509, and 0.550. This indicates that from 2018 to 2020, residents of Yunnan will have the highest human settlement quality index. (Fig. 5, Fig. 6, and Table 2).

In the second position, accounting for the highest number of times, is Sichuan. Sichuan ranked second

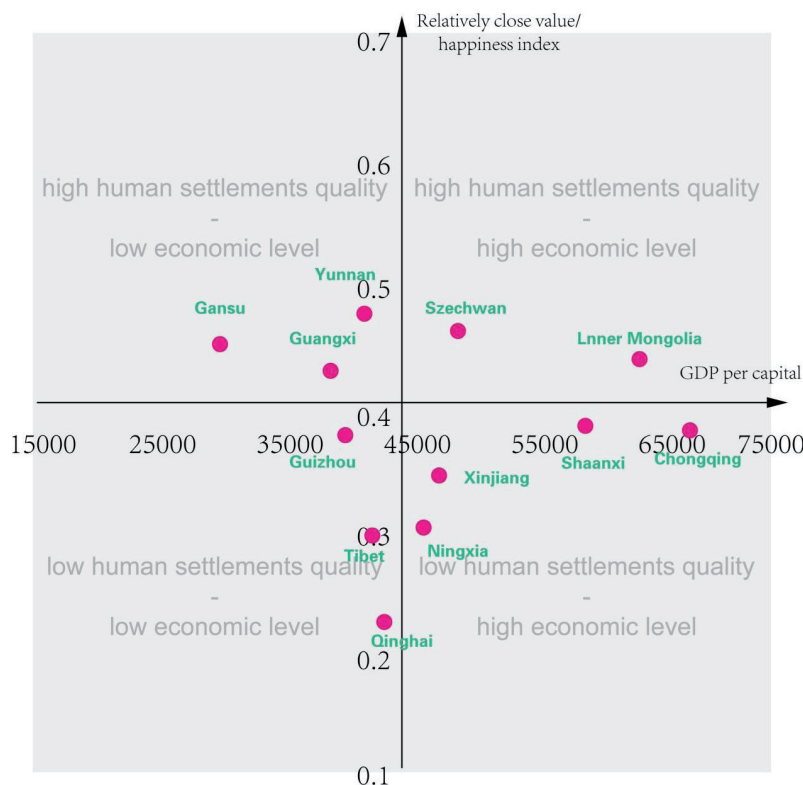


Fig. 4 Distribution of types by region in western China.

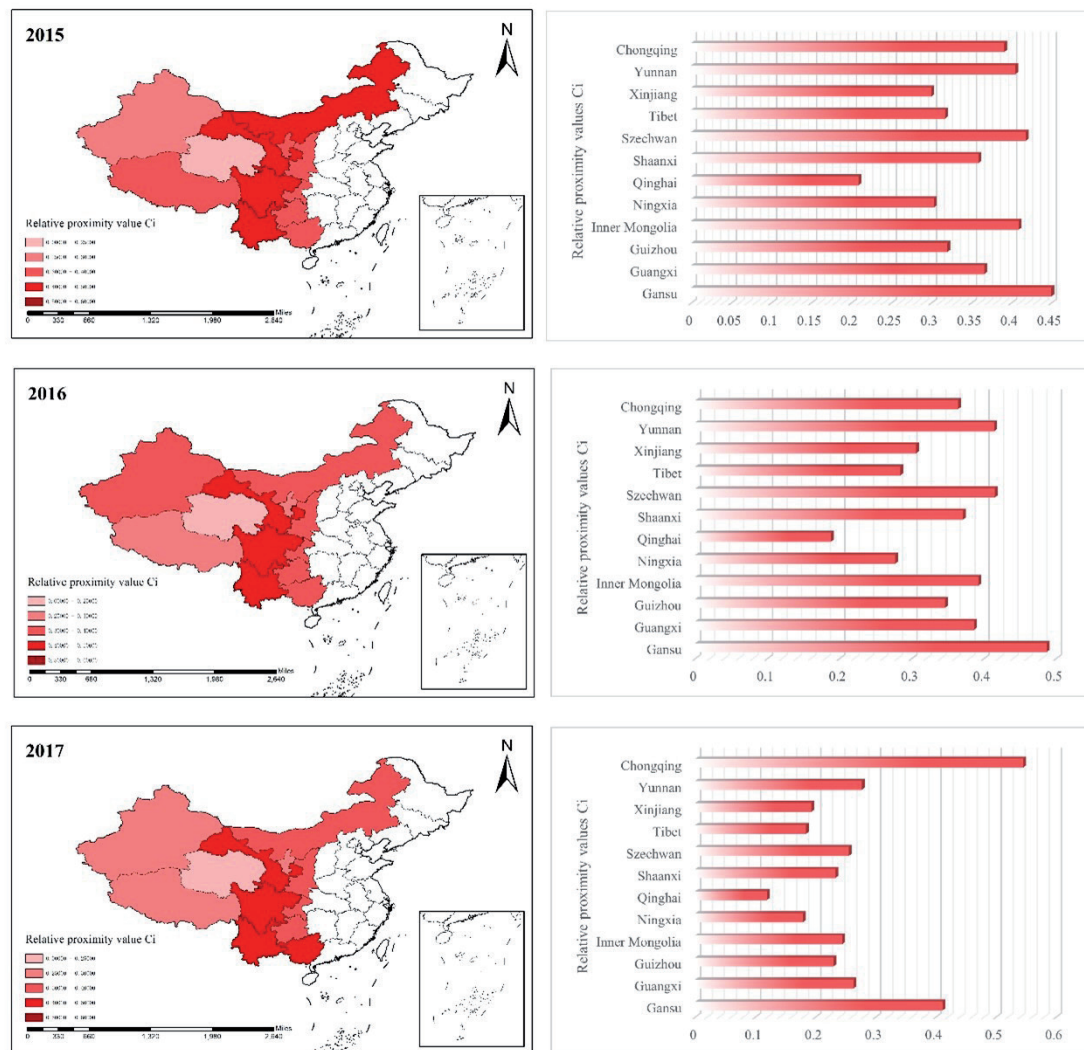


Fig. 5. Distribution of relative proximity C_i values (human settlement quality index) by provinces in western China, 2015-2017.

in relative proximity values in 2015, 2016, 2018, 2019, and 2020, with specific relative proximity C_i values of 0.418, 0.415, 0.472, 0.492, and 0.449. It can be seen that Sichuan has ranked second in the human settlement quality index five times across all the years studied, from 2015-2020. Meanwhile, Sichuan was ranked third in the relative proximity ranking in 2017. This shows that the human settlement quality index of Sichuan residents has been leading in western China and is relatively stable in the time dimension. Gansu held the first rank in relative proximity three times. However, in the overall calculation results and the overall relative proximity value ranking, Gansu has a lower relative proximity value than Sichuan. This illustrates the importance of balanced regional development. Even if a region cannot be ranked at the top of the overall human settlement quality index every year, it can have a high overall human settlement quality level as long as it focuses on coordinated and stable development (Table 2 and Fig. 6).

In the ranking of relative proximity values over the years, the relative proximity C_i values of Tibet, Ningxia,

Xinjiang, and Qinghai have consistently decreased over time, and Qinghai is more prominent. In the calculation results of all years, the relative proximity of Qinghai is always the lowest. At the same time, this final result is consistent with the comparative average score of relative proximity among the western Chinese provinces, i.e., the relative proximity C_i value for Qinghai is 0.209. In line with the findings of previous studies, it also ranks last. This shows that Qinghai residents have the lowest human settlement quality index (Fig. 5, Fig. 6, and Table 2).

Index Relative Comparison

The ranking of the magnitude of the corresponding indicators for each region in western China shows that X25 ranks first in the gray correlation of each region the most often, occurring twice. Among them, Inner Mongolia is 0.929 and Shaanxi is 0.667. In terms of numerical ranking, the X25 retail commodity price index has the highest correlation with the human

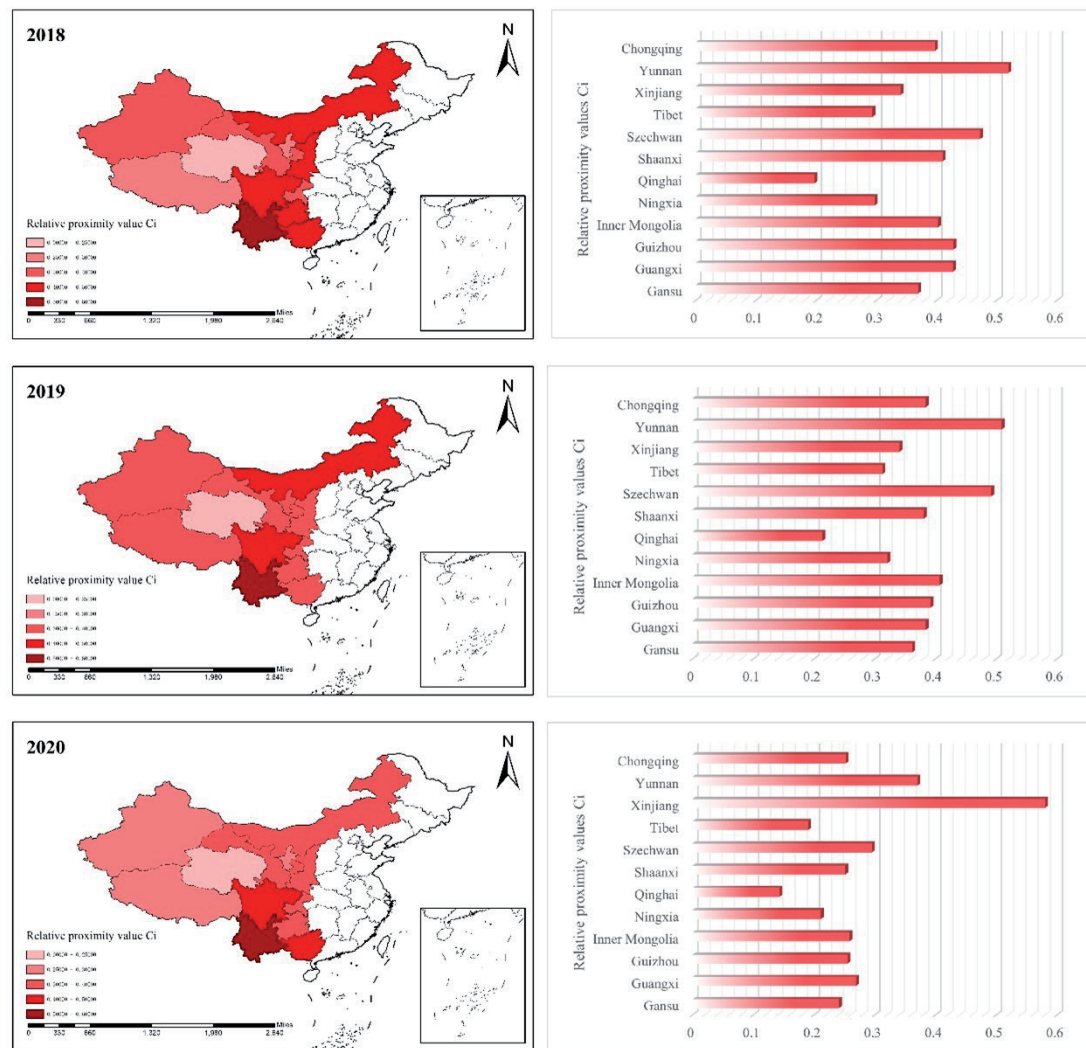


Fig. 6. Distribution of relative proximity C_i values (human settlement quality index) by provinces in western China, 2018-2020.

settlement environment index in the western region. The reason is that the commodity retail index can reflect the trend and extent of commodity price changes over time. It directly affects residents' living expenses and income and is closely related to the quality of the living environment and the conditions of the residents. X13 appears most frequently in the first 5 gray scales of each area and appears a total of 5 times. Among them are Guangxi (0.914), Inner Mongolia (0.920), Ningxia (0.858), Tibet (0.900), and Chongqing (0.988). In terms of distribution frequency, the combined population coverage of X13 radio programs has a correlation with the human settlement quality index in the western region. This is because the population coverage of radio programs can indirectly reflect the level of infrastructure development in a region. The higher the population coverage of radio programs, the higher the possibility of access to transportation, technology, and culture in the area. As a result, it will provide a higher public service experience for nearby residents, which in turn will enhance the construction of human settlement quality in the region. X24 appears a total of four times in the

top five gray correlation rankings for each region. X1 also appears four times in the top five gray correlation rankings for each region, with Guangxi (0.919), Qinghai (0.830), Shaanxi (0.989), and Chongqing (0.989). Among them are Guangxi (0.919), Qinghai (0.828), Shaanxi (0.667), and Xinjiang (0.864). The results show that the X24 consumer price index and X1 life expectancy per capita have some high correlation with the human settlement quality index in the western region in terms of distribution frequency. Among the lowest quintiles of gray correlations by region, X8 appears most frequently with 8 times. Specifically, Guizhou (0.717), Inner Mongolia (0.687), Ningxia (0.501), Shaanxi (0.662), Sichuan (0.513), Xinjiang (0.513), Yunnan (0.554), and Chongqing (0.651). The results showed that the correlation between X8 passenger traffic and the human settlement quality index was the lowest in size classification and distribution frequency in the western region. X10 occurs six times in each region in gray relational order. On the other hand, X2 and X33 appear a total of 5 times in the bottom 5 of the gray correlation ranking across regions; X18 and X31 appear a total

of 4 times in the bottom 5 of the gray correlation ranking across regions. This indicates that X10 car ownership per 10,000 population, X2 total number of traffic accidents per 10,000 population, X33 number of registered urban unemployed, X18 number of schools per 10,000 population, and X31 centralized sewage treatment are less correlated with the western human settlement quality index in terms of frequency distribution (Fig. 3).

Discussion

Similarities and Differences

There is a long history of international research into human settlement quality. This study is dedicated to exploring feasible measures to evaluate the human settlement quality index of residents. There are many correlations and similarities between this study and existing studies, as well as points of innovation and difference that are unique. From the same perspective, firstly, we found that a combination of TOPSIS entropy and gray entropy correlation is used to study the human settlement quality index of West China residents. This method is based on the methodology of previous studies. For example, Zhu, Wentao, et al. used gray correlation analysis, hierarchical analysis, and the entropy technique to assemble an index system to assess China's competitiveness. They assessed the competitiveness of 51 listed Chinese pharmaceutical companies [36]. In this study, the TOPSIS method with entropy weighting is used. Following previous studies, it analyzes the strengths and weaknesses of residents' well-being index in different regions of western China and can be successfully used to study the spatial distribution of residents' well-being index. The gray correlation between each of the comparative indices and the resident human settlement quality index can likewise be derived by means of the gray correlation evaluation method, which then yields the elements that have an impact on human settlement quality. This provides substantial assistance to the objectives of this study. It will not only help in the future development and construction of western China, but will also facilitate the construction of a future human settlement in western China, thus promoting quality development. Secondly, this paper's evaluation of the human settlement quality index for residents of western China builds upon the findings of previous research. The establishment of a comparative index is crucial for comparative studies.

The building of the comparison index device and the choice of comparison indexes in this study are primarily based on the full reference of the preceding lookup result. There are numerous factors influencing the human settlement quality index, and the selection and determination of its evaluation indicators must be done by reviewing information and literature. This can

make the evaluation indexes and evaluation system of this study more precise and detailed, while at the same time making this study scientific and feasible compared to the previous studies.

The study's location in Western China is specific to differentiating factors and distinguishes economically developed coastal areas from rural areas in Central China. It provides evidence for similar improvements in western China in the future. The extent of residential development in economically less developed areas is currently under-researched. This is because environmental characteristics and resources vary from region to region. At the same time, people's quality of life is influenced by many other factors. People living in economically less developed regions have worse living conditions and social protection than people living in economically more developed regions. Research and analysis of local quality of life can help local authorities improve local living conditions. The study analyzes data on various assessment indicators in western China and examines the strengths and weaknesses of settlement quality in different regions. It also highlights a number of social problems that currently exist in western China. The effect of such findings could provide a research base for discovering the construction of human settlements in distant areas and enrich the study of global social public service assessment. This contributes in part to the development and progress of humanity as a whole. Secondly, based on the GIS spatial visualization tool, a comparative analysis of the human settlement quality index for each region in western China was conducted to further explore the spatial distribution patterns of human settlement quality. The results of this assessment were able to derive a spatial distribution pattern of human settlement quality in western China. Based on the distribution sample, the western regions of China were classified into four specific regional types. This provides a strong basis for inquiry for future research into the assessment of human settlement quality in China. Next, the relationship between residents' social and public service indices and their influencing factors was further explored. This study further dissects the subtle relationship between various influencing factors and the human settlement quality index of residents in Western China through grayscale correlation analysis. The results of this study are more meaningful than existing research and have important theoretical and practical implications for western China, which wishes to improve its level of survival and social development.

Problems and Shortcomings

It should be noted that the study has a number of problems and shortcomings. Some of the assessment indicators are not currently included in the indicators for this study. In the development and collection of indicators, statistics varied from region to region. This means that in some regions, the indicators in question either had no data or insufficient data.

Adjustments to evaluation metrics can only be made when baseline data is missing or available. During this process, the assessment indicators were repeatedly reviewed, and some assessment indicators were finally deleted. Therefore, the final evaluation index system of this study does not provide a comprehensive and accurate overview and description of the local human settlements. This is the greatest shortcoming of this study.

Conclusion

The study above has revealed four main points. First, from the perspective of the overall index of human settlements, among the 12 western regions, Yunnan has the highest index of human settlements, followed by Sichuan and Gansu. The relative C_i distances of these three regions are 0.478, 0.441, and 0.434, respectively. The Qinghai settlement rate is the lowest among the 12 regions in the west. Qinghai Province has the lowest C_i value at 0.209. Of course, we must focus on improving. The relative proximity value of C_i for Qinghai is 0.209. It is obvious that we need to focus on improving the construction of human settlements in Qinghai. Based on the above studies, the authorities should gradually improve the consumer price index, the retail price index, the ratio of full-time teachers to the population, the number of full-time teachers per 10,000 inhabitants, and the life expectancy per inhabitant. This will improve the human settlement quality index of Qinghai society and promote the harmonious development of Qinghai.

Second, the habitat index for each region in western China varies between 0.2 and 0.6 between 2015-2020, and the spatial pattern of the distribution of habitat quality in western China is generally higher in the southeast and lower in the northwest. At the same time, balanced regional development is very important for human settlements. Even if a region is not at the top of the human settlement quality index every year, a focus on the coherence and stability of social development can lead to lasting, high-quality human settlement quality for the local area. Therefore, we must focus on all aspects of a region's quality. Each aspect must be coordinated to promote the development and progress of a region in a comprehensive and systematic way.

Third, there is no positive relationship between economic development and human settlement quality. According to the results of the study, western China was divided into different types according to human settlement quality and the degree of economic development. Sichuan Province and Inner Mongolia Autonomous Region belong to the category of "high human settlement quality-high economic level". Shaanxi, Chongqing, Xinjiang, and Ningxia belong to the "low human settlement quality-high economic level" type; Yunnan, Gansu, and Guangxi belong to the "high human settlement quality-low economic level" type. Guizhou, Tibet Autonomous Region, and Qinghai

belong to the "low human settlement quality-low economic level" type. Therefore, we need to focus on the "low human settlement quality-high economic level" and "low human settlement quality-low economic level" regions. Improvement based on the indicators with a high gray correlation in each region can significantly improve the human settlement quality level of a region.

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Conflict of Interest

The authors declare no conflict of interest.

References

- LIU F., DING Y. Research on urban ecological environment problems and sustainable development. IOP Conference Series. Earth and Environmental Science, **568** (1), 012014, **2020**.
- WEI Z., HULIN L., XUEBING. A. Ecological civilization construction is the fundamental way to develop low-carbon economy. Energy Procedia, **5**, 839, **2011**.
- XU L., SHU X., HOLLERT H. Aggregate risk assessment of polycyclic aromatic hydrocarbons from dust in an urban human settlement environment. Journal of Cleaner Production, **133**, 378, **2016**.
- MENGIST W., SOROMESSA T., FEYISA G.L. Landscape change effects on habitat quality in a forest biosphere reserve: Implications for the conservation of native habitats. Journal of Cleaner Production, **329** (129778), 129778, **2021**.
- HE J. A theoretical thinking about ecological civilization construction. Proceedings of the 2017 6th International Conference on Energy and Environmental Protection, Atlantis Press, pp. 665, **2017**.
- FANG C., FAN Y., BAO C., LI G., WANG Z., SUN S., MA H. China's improving total environmental quality and environment-economy coordination since 2000: Progress towards sustainable development goals. Journal of Cleaner Production, **387** (135915), **2023**.
- CUIJIAO X.Z. Development Thread and Evolution Logic Concerning Ecological Civilization Thought of the Communist Party of China: Based on the Report Analysis of the Party's 8th to 20th National Congresses. Journal of Central South University of Forestry & Technology (Social Sciences). **2023**.
- ZHU T., GAO S. Promoting circular development and recycling solid waste-In the view of ecological civilization construction. Advanced Materials Research, **878**, 873, **2013**.
- MAO Q. Theory and practice of the science of human settlements in China. Urban Planning International, **34** (4), 54, **2019**.
- WU L. Sciences of human settlements: Searching for the theory and practice. Ekistics; Reviews on the Problems and Science of Human Settlements, **69** (415-417), 279, **2002**.

11. WU L. Wu Liang Yong: should actively create the discipline of human habitat. *Bulletin of Chinese Academy of Sciences*, (6), 442, **2006**.
12. D'ANJOU R.M., BRADLEY R.S., BALASCIO N.L., FINKELSTEIN D.B. Climate impacts on human settlement and agricultural activities in northern Norway revealed through sediment biogeochemistry. *Proceedings of the National Academy of Sciences*, **109** (50), 20332, **2012**.
13. LI W., LI P., FENG Z., XIAO C. GIS-based modeling of human settlement suitability for the Belt and Road regions. *International Journal of Environmental Research and Public Health*, **19** (10), 6044, **2022**.
14. FORSBERG A., VON MALMBORG F. Tools for environmental assessment of the built environment. *Building and Environment*, **39** (2), 223, **2004**.
15. KLUNDER G. Environmental impact of Dutch dwellings: Priorities for reduction and benefits of sustainable construction. In *The Geo Journal Library*, Springer Netherlands, pp. 109, **2001**.
16. BOSCHMANN E.E., GABRIEL J.N. Urban sustainability and the LEED rating system: a case study of regional characteristics and adaptive use in green building in Denver and Boulder, Colorado. *The Geographical Journal*, **179** (3), 221, **2013**.
17. SUN Y., ZHANG Q., YU H., YAN T. Quality assessment for Human Settlement of Urban Community based on remote sensing technology. In: *Proceedings 2011 IEEE International Conference on Spatial Data Mining and Geographical Knowledge Services*. IEEE, pp. 417, **2011**.
18. YI C. An ecological perspective and the construction of habitats that integrate nature. *Time Architecture*, (3), **1995**.
19. CHEN X., LI S. Resilient Governance of Rural Residential Environment in the Context of Rural Revitalization: Mechanism and Path. *Journal of South China University of Technology*, (Social Science Edition), **25** (3), 116, **2023**.
20. YUN Z. Transcending "Dual Game": A Study on the Practice of Rural Human Settlement Environment Improvement from the Perspective of Balanced Administration and Autonomy. *Journal of Huazhong Agricultural University* (Social Sciences Edition), (1), 165, **2023**.
21. ZHOU K. Factors influencing the quality of rural human settlement. *Sina peripheral metro polytan are abased nonstructural equation model: A case study from Beijing*. *Chinese Journal of Population Resources and Environment*, **12** (4), 301, **2014**.
22. YANG W., ZHAO J., ZHAO K. Analysis of regional difference and spatial influencing factor of rural human settlement ecological environment in China. *Sustainability*, **10** (5), 1520, **2018**.
23. ZHANG Z.Q., XU Z.M., CHENG G.D., CHEN D.J. The Ecological Footprints of the 12 Provinces of West China in 1999. *Acta Geographica Sinica*, **5**, 598, **2001**.
24. NIU D., WU Q., FAN L., LIU C. The comprehensive evaluation and study based on national happiness index system. In *2013 International Conference on Education, Management and Social Science*, ICEMSS-13 Atlantis Press, pp. 204, **2013**.
25. CHEN Z.X., XU J. Evaluation of urban happiness index based on TOPSIS and grey correlation analysis. *Statistics & Decision*, **37** (4), 59, **2021**.
26. LIN S., HOU L. SDGs-oriented evaluation of the sustainability of rural human settlement environment in Zhejiang, China. *Heliyon*, **9** (2), e13492, **2023**.
27. YANG Q., FAN J.C. Assessment of Human Settlement Quality Based on the Population Exposure Risk to PM_{2.5} Pollution in the Mid-Spine Belt of Beautiful China. *Sustainability*, China, **15** (19), 14648, **2023**.
28. SHI J.Y., SUN J.Q. Prefabrication Implementation Potential Evaluation in Rural Housing Based on Entropy Weighted TOPSIS Model: A Case Study of Counties in Chongqing, China. *Sustainability*, China, **15** (6), 4906, **2023**.
29. LIU D., QI X., FU Q., LI M., ZHU W., ZHANG L., ABRAR FAIZ M., KHAN M.I., LI T., CUI S. A resilience evaluation method for a combined regional agricultural water and soil resource system based on Weighted Mahalanobis distance and a Gray-TOPSIS model. *Journal of Cleaner Production*, **229**, 667, **2019**.
30. GUO Y., CHEN P., ZHU Y., ZHANG H. Study on comprehensive evaluation of human settlements quality in Qinghai Province, China. *Ecological Indicators*, **154**, 110520, **2023**.
31. SHEKHAR H., SCHMIDT A.J., WEHLING H.W. Exploring wellbeing in human settlements - A spatial planning perspective. *Habitat International*, **87**, 66, **2019**.
32. ZHANG T., HE D., KUANG T., CHEN K. Effect of rural human settlement environment around nature reserves on farmers' well-being: A field survey based on 1002 farmer households around six nature reserves in China. *International Journal of Environmental Research and Public Health*, **19** (11), 6447, **2022**.
33. ZHOU L.B., LI G., CHI G.T. The Comprehensive Evaluation of the Human All-Round Development Based on G1- Standard Deviation and Empirical Study. *Chongqing, China*, Volumes **50-51**, pp. 823, **2011**.
34. ZANG Z., ZOU X., SONG Q., LI Y., WANG T. Integrated sustainable development evaluation based on human well-being indices and pressure indices: A case study of the South China Sea Neighboring Countries. *The Social Science Journal*, **54** (3), 346, **2017**.
35. SONG Y., YU Y., LIU Y., LIU Z., LI Q., XU G. Analysis and Visualization of the Urban Residents' Income-Related Happiness Index in China. In *Advances in Cartography and GIS science: Selections from the International Cartographic Conference*, **28**, pp. 295, **2017**.
36. ZHU W., DUAN L., ZHANG J., SHI Y., QIAO Y. Constructing a competitiveness evaluation system of listed Chinese medicine enterprises based on grey correlation. *The Journal of Grey System*, **27** (4), 40, **2015**.