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Spatiotemporal Evolution and Driving Forces of Sustainable Development of Urban Human Settlements in China for SDGs

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Abstract: As the world's largest developing country, China has actively implemented the UN Sustainable Development Goals (SDGs). Sustainable development of urban human settlements is the result of localization and the deepening of sustainable development theory in China. This study combines SDGs to construct an evaluation index system for the sustainable development of urban human settlements in China, using optimization methods, such as natural breaks (Jenks), exploratory spatial data analysis, and GeoDetector, to conduct systematic research on the spatiotemporal evolution of the current sustainable development level and analyze the core driving forces of urban human settlements in 285 prefecture-level cities in China from 2000 to 2019. Our study revealed that: (1) The overall sustainable development level of urban human settlements and their subsystems in China has improved steadily, but the levels of subsystems are quite different; (2) the sustainable development level of the urban human settlements in China can be expressed as a spatial pattern of "high in the east and low in the west, high in the south and low in the north" and has relatively significant spatial correlation characteristics; notably, the development level of each subsystem has different spatial characteristics; (3) the sustainable development level of urban human settlements is mainly based on medium sustainability, and the main development model is to progress from a medium-low development level to a medium-high development level; (4) the sustainable development level of urban human settlements is mainly driven by the per capita gross domestic product (GDP), housing price-to-income ratio, investment in education and scientific research, Internet penetration, and $PM_{2.5}$.

Keywords: urban human settlements; sustainable development; temporal and spatial differentiation; driving force; prefecture-level cities in China

Citation: Cong, X.; Li, X.; Gong, Y. Spatiotemporal Evolution and Driving Forces of Sustainable Development of Urban Human Settlements in China for SDGs. *Land* **2021**, *10*, 993. https://doi.org/10.3390/land10090993

Academic Editor: Ayyoob Sharifi

Received: 10 August 2021
Accepted: 18 September 2021
Published: 21 September 2021

1. Introduction

Since the reform and opening up, China's economy has developed rapidly; the urbanization rate has increased, and the scale of urban space has expanded [1]. At the same time, human settlements are also being threatened [2], especially with the outbreak of the COVID 19 epidemic, and the global problems of human settlements, such as pollution, education interruption, economic loss, and medical resource imbalance that are becoming more prominent [3]. The United Nations convened the Human Environment Conference in Stockholm in 1972 and issued the United Nations Declaration of the Human Environment, which was the first meeting where the international community discussed the severe contradiction between the environment and development [4]. In 1987, the concept of sustainable development was clearly stated for the first time in Our Common Future [5]. Ever since, managing and developing human settlements and realizing sustainable development have become the focus of attention for all global economies. In September 2015, the United Nations General Assembly officially adopted the 2030 Agenda for Sustainable Development, which further clarified the sustainable development goals (SDGs) and the corresponding implementation methods [6]; the agenda also promoted continuous deepening of the concept of sustainable development and improvement of the world's living environment (at a broader level and scope). As the world's largest developing country, China has always believed that peace and development are crucial for the times we live in, and globalization and multilateralism are the signs of world development [7]. Therefore, in the process of global sustainable development, starting from the global responsibility of building a community with a shared future for mankind, the country has actively responded and made important strategic deployments in the corresponding directions. Human settlements are the basis of human survival and activities, and a prerequisite for the stable development of society. The scientific concept behind them aims to find a high degree of compatibility between material and non-material environments, an ideal relationship between humans and the environment, and conformity to the objective laws regarding the development of human settlements [8]. The effective combination of urban human settlements and sustainable development can ensure the efficient operation of various systems of human settlements, while securing high-quality human settlement resources for future generations. Notably, the sustainable development of human settlements is the result of localization and deepening of sustainable development theory in China, and it is also a crucial practice and national model for adhering to the UN sustainable development goals [9].

The construction of urban human settlements has yielded relatively fruitful results. According to the different research propositions, studies on foreign urban human settlements are divided into the urban planning school, Chicago school, ekistics school, and ecological school [8,10]. Human settlements have been through a dynamic process of change, and notably, there are certain differences between cities or countries. The assessment and comparative analysis of urban human settlements are not only the basis for measuring urban planning, construction, and management, but also an effective way to highlight the gaps in urban development and identify urban problems. Therefore, the temporal and spatial dynamic evolution of urban human settlements has been the focus of research. Many scholars have considered the system coordination [11], vulnerability [12], suitability [13], wellbeing [14], satisfaction [15,16], pseudo-environment [17], and the reorganization by COVID 19 [18] of urban human settlements based on different dimensions and perspectives. Owing to the newfound focus on earth, studies on human settlements from the perspective of sustainable development have become a new research hotspot [19,20]. An increasing number of scholars believe that it is necessary to firmly build the evaluation standard of urban human settlements based on people and optimize the sustainable development route of urban human settlements [21,22]. Regarding the relevant research on the sustainable development of urban human settlements, Mele (2018) proposed that whether it is an old, industrialized country or an emerging country, if the sustainable development of human settlements is to be achieved, it is necessary to rethink the economy and development model [23]. Dahiya (2019) explained that the urban human settlements in the Asia-Pacific region still have problems, such as urban poverty, inequality, and insufficient urban public service resources, and emphasized that the New Urban Agenda can effectively resolve the current global sustainability and inclusiveness issues [24]. Corbane (2020) conducted an analysis of changes in the greenness of human settlements in 10,323 urban centers around the world, believed that the greening degree of most urban centers is lower than that outside built-up areas, and explained that the difference in human settlements between cities may also be caused by social and political factors [25]. Plata (2019) proposed that green infrastructure planning should not be limited to ecology; it should be integrated with the social environment to improve the capacity of sustainable development of urban human settlements [26]. Additionally, Rozhenkova (2019) emphasized that to achieve sustainable development of urban human settlements, a city policy database should be established for comparison [27]. Wang (2020) proposed that only when the built environment and the natural ecological environment reach a balance point can the sustainable development of human settlements be realized [28]. Wang (2020) also postulated that the sustainable development of human settlements can further improve the ecological well-being of residents [29]. With respect to research methods, Osman (2021) developed the Voluntary Local Review framework to evaluate and monitor the progress of urban human settlements in

Saudi Arabia to achieve SDGs [30]. Gonçalves (2020) believed that the Casa Azul Label and SBTool Urban Dahiya can be suitable for assessing the sustainability potential of human settlements in small towns of developing countries [31]. Xu (2019) applied the full permutation polygon synthetic indicator to evaluate the sustainability of China's urban agglomerations, and believed that the development of urban human settlements should still focus on coordination [32]. Botequilha-Leito (2020) used the strengths, weaknesses, opportunities, and threats (SWOT) method to analyze the role of performance-based planning in solving the sustainable problems of urban human settlements in Queensland [33].

In addition to different theoretical studies, different countries have different construction priorities and methods for the sustainable development of human settlements. For example, in addition to the importance of resources and the environment, the United Kingdom's evaluation criteria for human settlements involve social justice and public participation. In practice, with the city of London as the center, eight satellite cities that can not only meet the needs of life but also provide employment have been created in a concentric circle pattern; this not only helps to achieve self-sufficiency in the region, but also ensures good human settlements [34]. Germany's focus on the construction of human settlements has changed from its initial emphasis on increasing the number of residences to improving the quality of human settlements and promoting urban development based on a sustainable natural ecological environment [35]. The Netherlands has implemented reasonable plans for land use and transportation to avoid environmental pressure caused by high density, while paying attention to the construction of urban green spaces [36]. The United States of America aims at livability, health (including social, psychological, and well-being), and sustainability (including environmental problems, the disorderly spread of land, and resource consumption), to guide the sustainable development of human settlements [37]. The Chinese human settlements science considers the global, regional, city, community (village and town), and architecture at different levels, outlines natural, humanity, social, residential, and support systems as the five crucial parts of human settlements, and puts forward a sustainable development plan for human settlements [8]. Singapore adheres to the "people-oriented" principle, starting from the perspective of residents' lives, such as air quality, traffic accessibility, urban greening, and infrastructure, and attaches importance to the construction of ecological environments to build a garden city [38].

Although there have been fruitful theoretical and practical results on the improvement and development of urban human settlements, the related studies that combine urban human settlements with sustainable development are mostly theoretical discussions. These studies seldom used quantitative indicators for systematic research. Therefore, to understand the overall, continuous, and dynamic evolution of the sustainable development of urban human settlements in all prefecture-level cities in China, our study addressed the following problems: What kind of development law is implemented at the national level for the sustainable development of urban human settlements? What is the level of sustainable development of the urban human settlements of each city in China, and what are its spatiotemporal evolution characteristics? What causes the difference in the level of sustainable development across urban human settlements? The answers to these questions cannot only enrich the quantitative research on the sustainable development of urban human settlements, but also provide experience and reference to improve the quality of urban human settlements, guide the accurate positioning of various cities, and formulate urban development strategies rationally. This study considers the theory of sustainable development as the cornerstone for the construction of urban human settlements, and develops evaluation indicators and models for the sustainable development of urban human settlements under the guidance of the 2030 SDGs. Additionally, this study conducts a quantitative test of the sustainable development process of urban human settlements in various Chinese cities from 2000 to 2019. The objectives of this study are to explore the external manifestations and internal driving forces of the spatiotemporal evolution of sustainable development in urban human settlements in China over the past 20 years, improve the sustainable development capacity of urban human settlements, and finally, realize the Chinese practice of global sustainable development.

2. Data and Methods

2.1. Overview of Study Area

China is located in eastern Asia and the west coast of the Pacific Ocean, bordered by North Korea to the east, Mongolia to the north, Afghanistan, Pakistan, and India to the west, and Myanmar, Laos, and Vietnam to the south. China starts from the heart of the Heilongjiang River in the north, to the Lydi Shoal in the south, and from the Pamirs in the west, to the intersection of the Heilongjiang and Wusuli rivers in the east. The total land area of China is about 9.6 million square kilometers, ranking third in the world. The terrain of China is high in the west and low in the east, and the climate types are diverse. The resources are abundant, but the per capita resources are relatively small; the regional distribution is uneven. China is the most populous developing country in the world. According to official data released in May 2021, the total population of the country is 1411.78 million, with a sex ratio of 105.07%. The population living in urban areas accounts for 63.89%, and the population aged 65 and above accounts for 13.50%. Notably, China is the second largest economy in the world, and the country's GDP in 2020 was 101,598.6 billion yuan, reflecting an increase of 2.3% over 2019, of which the secondary and tertiary industries accounted for 37.8% and 54.5%, respectively.

As of 2020, China has 34 provincial-level administrative divisions and 333 prefecture-level administrative divisions (including 293 prefecture-level cities). Notably, we have considered 2000–2019 as the research period. To facilitate research, the administrative divisions of the country in 2020 have been considered, and Chaohu, Bijie, Tongren, Sansha, Haidong, Danzhou, Xigaze, Qamdo, Nyingchi, Turpan, Shannan, Hami, Nagqu, and Laiwu, whose data cannot be matched due to the adjustment of administrative divisions, are eliminated. A total of 285 prefecture-level cities, with relatively stable administrative divisions since 2000, are retained as the study subjects.

2.2. Data Source

The spatial vector data were obtained from the standard map service system (http://bzdt.ch.mnr.gov.cn, accessed on 1 January 2021). The statistical indicator data were derived from the China City Statistical Yearbook, China Urban Construction Statistical Yearbook, China Environmental Statistics Yearbook, provincial and municipal statistical yearbooks, official websites of statistical bureaus, and government bulletins from 2000 to 2020. The meteorological data were obtained from publicly released information from the Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, and Resources and Environmental Sciences and Data Center (http://www.resdc.cn/data.aspx?DATAID=230, accessed on 3 February 2021). The average $PM_{2.5}$ emission concentration was obtained from the world $PM_{2.5}$ concentration map jointly released by Columbia University and the U.S. Atmospheric Composition Group (http://beta.sedac.ciesin.columbia.edu/, accessed on 19 February 2021). The average annual $PM_{2.5}$ emission concentration of prefecture-level cities in China was obtained using ArcGIS. House price data were obtained from the CEIC database (https://www.ceicdata.com/en, accessed on 4 January 2021). The energy consumption data were derived from the night light data obtained by the integrated processing of DMSP/OLS data and NPP-VIIRS data; the energy consumption was simulated and calculated [39]. Part of the data referred to the result of arithmetic processing, such as the temperature and humidity index [40], wind efficiency index [41], foreign trade dependence, and road network density.

2.3. Construction of Indicator System for Sustainable Development of Urban Human Settlements Based on SDGs

The concept of human settlements was formed in the theory of ekistics proposed by the Greek scholar Dausatias in the 1950s. Because urban human settlements are complex giant systems, it is difficult to use a single index for its quantitative analysis, and therefore, it is mostly studied by constructing an index system [42,43]. Wu (2001) combined China's social reality and emphasized that human settlements include five major systems, namely, natural, humanity, social, residential, and support subsystems [8]. Urban human settlements and sustainable development promote each other, and the natural environment is the basis for humans to develop settlement behaviors and achieve sustainable development. As individual inhabitants, the material needs and psycho-physiological behaviors of human beings are the driving forces for a sustainable living environment. Appropriate housing for everyone is a prerequisite for a sustainable living environment. Society is a system of human interaction, and its economic development, social security, and stability are the basic requirements for a sustainable living environment. Furthermore, the infrastructure of human settlements and the fairness and efficiency of the public service system are strong supports for a sustainable living environment. Only when the five major systems are organically combined to ensure a virtuous circle and coordinated development within and among systems is achieved, can the human settlements be in a state of sustainable evolution.

To achieve steady progress in the quality and efficiency of the global ecological environment, economic structure, and social system, the UN SDGs identified by the United Nations Development Summit cover 17 goals and 169 specific targets, which were fully launched on 1 January 2016. This study considers the SDGs global indicator framework as an important basis for assessing the sustainable development of urban human settlements, while recognizing the China National Plan for implementing the 2030 Agenda for sustainable development as a supplement. In addition, this study refers to the China Human Settlements Award Evaluation Index System and relevant standards in domestic and foreign research results and closely integrates the indicators selected by the localization of SDGs, with the connotation of various systems of human settlements. Each indicator is matched to the five system layers of urban human settlements one by one, so that each indicator belongs to a certain system of human settlements and has a corresponding sustainable development goal to ensure the comprehensiveness of the selection of indicators.

The natural system includes geographic location, climatic conditions, animals and plants, and utilization of water and land resources. The ten indicators selected in this study from the three aspects of natural conditions, environmental protection, and resource utilization mainly corresponded to SDGs 6, 11, 12, and 15. The humanity system includes population development trends, population quality assurance, and improvement of quality capabilities. The nine indicators selected in this study from three aspects of population trends, cultural education, and scientific research and innovation mainly correspond to SDGs 1, 4, 5, 9, and 11. The residential system includes housing price, area, house type, parking space, water, electricity, and gas coverage. The five indicators of housing conditions and housing facilities selected in this study mainly correspond to SDGs 6, 7, and 11. A social system is a group formed by the interrelation of residents in the process of interacting with each other. This group is an organism that promotes social stability and harmony and is combined according to a certain normative system and economic relationship. The social system consists of nine indicators in three aspects, namely, economic level, living conditions, and urban safety, which mainly correspond to SDGs 2, 8, 10, 12, 14, and 16. The support system connects the artificial and natural systems. This is the result of man-made designs and construction. It is a guarantee system that provides support for human production and life. A total of seven indicators were selected in this study from three aspects of public services, communication facilities, and transportation that mainly correspond to SDGs 3, 9, and 11. Among them, SDG 13 focuses on national and global climate action strategies and plans. Considering the availability and comparability of its indicators, it was temporarily not included in the indicator system for the sustainable development of urban human settlements. As a result, constructing a multi-level urban human settlements sustainability evaluation index system (Table 1) that adapted to China's national and spatiotemporal conditions can not only improve the persuasiveness of the evaluation results but also enrich the hierarchy of the index system. This can explain China's substantive efforts for sustainable development strategies and construction of human settlements, along with the experience and lessons in the development process.

Table 1. Index system and weight of sustainable development of urban human settlements in China.

System Layer	Index Layer	Corresponding to SDGs	Entropy Method Weight	AHP Weight	Comprehensive Weight
Natural system	Temperature and humidity index (X_1)	SDG 11.6	0.0129	0.0671	0.0325
	Wind efficiency index (X_2)	SDG 11.6	0.0144	0.0283	0.0223
	$PM_{2.5}$ concentration (X_3)	SDG 11.6	0.0292	0.0379	0.0368
	Green coverage rate in built-up area (X_4)	SDG 15.2	0.0178	0.0528	0.0339
	Park green area per capita (X_5)	SDG 11.7	0.0209	0.0196	0.0224
	Sewage treatment rate (X_6)	SDG 6.3	0.0153	0.0528	0.0314
	Harmless treatment rate of domestic garbage (X_7)	SDG 11.6	0.0145	0.0240	0.0206
	Water consumption per unit GDP (X_8)	SDG 6.4	0.0468	0.0501	0.0535
	Energy consumption per unit of GDP (X_9)	SDG 12.2	0.0130	0.0125	0.0141
	Comprehensive utilization rate of industrial solid waste (X_{10})	SDG 12.5	0.0133	0.0691	0.0335
Humanity system	The population density (X_{11})	SDG 11.3	0.0125	0.0333	0.0225
	Natural growth rate (X_{12})	SDG 11.3	0.0113	0.0178	0.0157
	Sex ratio (X_{13})	SDG 5.1	0.0111	0.0096	0.0114
	Aging rate (X_{14})	SDG 11.3	0.0151	0.0178	0.0181
	Number of college students per 10,000 (X_{15})	SDG 4.3	0.0199	0.0140	0.0185
	Compulsory education teacher-student ratio (X_{16})	SDG 4.1	0.0135	0.0124	0.0143
	Percentage of education expenditure (X_{17})	SDG 1.a	0.0360	0.0095	0.0204
	R&D investment intensity (X_{18})	SDG 9.5	0.0491	0.0295	0.0420
	Number of patents granted per 10,000 people (X_{19})	SDG 9.5	0.0139	0.0098	0.0129
Residential system	Housing area per capita (X_{20})	SDG 11.1	0.0414	0.1014	0.0716
	House price to income ratio (X_{21})	SDG 11.1	0.0275	0.0338	0.0337
	Per capita residential investment (X_{22})	SDG 11.1	0.0340	0.0338	0.0374
	Water supply penetration rate (X_{23})	SDG 6.1	0.0137	0.0338	0.0238
	Gas penetration rate (X_{24})	SDG 7.1	0.0191	0.0113	0.0162
Social system	GDP per capita (X_{25})	SDG 8.1	0.0572	0.0236	0.0406
	The proportion of tertiary industry in GDP (X_{26})	SDG 8.2	0.0279	0.0137	0.0216
	Public fiscal revenue as a proportion of GDP (X_{27})	SDG 8.1	0.0287	0.0087	0.0175
	Export dependence (X_{28})	SDG 17.11	0.0261	0.0047	0.0122
	Urban registered unemployment rate (X_{29})	SDG 10.2	0.0223	0.0158	0.0207
	Per capita disposable income growth rate (X_{30})	SDG 8.1	0.0229	0.0240	0.0259
	Per capita food production (X_{31})	SDG 2.1	0.0223	0.0129	0.0187
	Per capita aquatic product output (X_{32})	SDG 14.4	0.0283	0.0042	0.0120
	Number of criminal cases per 10,000 people (X_{33})	SDG 16.1	0.0221	0.0284	0.0277
Support system	Number of physicians per 10,000 people (X_{34})	SDG 3.8	0.0317	0.0249	0.0310
	Number of stadiums owned by 10,000 people (X_{35})	SDG 9.1	0.0300	0.0031	0.0107
	Number of cultural centers owned by 10,000 people (X_{36})	SDG 11.4	0.0256	0.0031	0.0098
	Mobile phone penetration rate (X_{37})	SDG 9.c	0.0422	0.0132	0.0261
	Internet penetration rate (X_{38})	SDG 9.c	0.0473	0.0132	0.0276
	Road network density (X_{39})	SDG 11.2	0.0125	0.0068	0.0102
	Number of buses owned by 10,000 people (X_{40})	SDG 11.2	0.0368	0.0178	0.0283

2.4. Research Methods

1. Coefficient of variation

The coefficient of variation is statistically used to characterize the degree of dispersion of the data. In this study, the coefficient of variation is used to calculate the relative difference between all the values of a certain indicator of the sustainable development of human settlements in China. The calculation formula is as follows:

$$CV = \frac{\sigma}{\mu} \quad (1)$$

where σ is the standard deviation, μ is the average value, and CV is the coefficient of variation. The larger the CV value, the larger the relative gap in the data.

2. Standardization of evaluation indicators

Because of the different attributes of evaluation indicators related to the sustainable development of urban human settlements in China, to eliminate the impact of different indicators on the same measurement unit, it is necessary to standardize the indicator data of different units and attributes, and convert them into data that have the same measurement and are directly operable. Notably, the larger the positive index value, the better the performance. The calculation formula is as follows:

$$X_{ij} = \frac{x_{ij} - \min\{x_{ij}\}}{\max\{x_{ij}\} - \min\{x_{ij}\}} \quad (2)$$

Conversely, the smaller the value of the reverse index, the better the performance. The calculation formula is as follows:

$$X_{ij} = \frac{\max\{x_{ij}\} - x_{ij}}{\max\{x_{ij}\} - \min\{x_{ij}\}} \quad (3)$$

where X_{ij} represents the standard value of the evaluation index i of the evaluation object j, x_{ij} represents the original value, and $\max\{x_{ij}\}$ and $\min\{x_{ij}\}$ represent the maximum and minimum values of the original values, respectively.

3. Combination weight determination

The subjective and objective combination method uses the objective weighting method, which is based on the entropy and subjective weighting methods of the analytic hierarchy process, to determine the indicator weights of the evaluation system for the sustainable development of urban human settlements. After calculating the weights of the entropy method and the analytic hierarchy process separately, the two are combined to form a new weight, using the Lagrangian multiplier method. This method can effectively avoid the shortcomings of the objective weighting method, namely, poor participation by decision makers and limited scope of use, and reduces the error caused by the subjective weighting method when there are too many indicators. At the same time, the advantages of the objective weighting method with high accuracy and the subjective weighting method with strong systematics can be maximized to improve the accuracy of the weight calculation results. The calculation formula is given by [44]:

$$W_j = \frac{(w_{1j}w_{2j})^{0.5}}{\sum_{j=1}^{n}(w_{1j}w_{2j})^{0.5}} \quad (4)$$

where W_j is the combined weight of the j-th index, and w_{1j} and w_{2j} are the objective and subjective weights of the jth index, respectively.

4. Measurement model of sustainable development of urban human settlements

The recently proposed sustainable development index research framework by the University of Texas at Arlington [45] improved the ability to measure the sustainable development level of human settlements of different cities in different years. First, the sustainable development level of the natural, humanity, residential, social, and support systems in urban human settlements were calculated. Then, the comprehensive sustainable development level was calculated. The higher the value, the higher the sustainable development level of the city's human settlements. The calculation formula is as follows:

$$s_i = \sum_{j=1}^{n}(w_j \times X_{ij}) \quad (5)$$

$$S = \sum_{i=1}^{m}(W_i \times s_i) \quad (6)$$

where s_i is the sustainable development level of each subsystem of urban human settlements, w_j is the weighted value of each index, X_{ij} is the standardized index value, S is the sustainable development level of urban human settlements, and W_i is the weighted value for each system layer.

5. Exploratory spatial data analysis method

Spatial autocorrelation is a common method of exploratory spatial data analysis that refers to the association of eigenvalues between a spatial unit and its neighboring units. The evaluation methods for spatial autocorrelation are divided into two categories: Global spatial autocorrelation and local spatial autocorrelation. Global spatial autocorrelation mainly describes the overall distribution of a certain feature in space and whether there is an aggregation feature. If this exists, we further analyze the model data related to the local space. This study uses spatial autocorrelation to reflect the spatial correlation pattern of the sustainable development level of urban human settlements. The global spatial autocorrelation evaluation method uses the Moran global spatial autocorrelation coefficient, and local spatial autocorrelation uses local indicator of spatial association (LISA) indicators.

6. GeoDetector

The GeoDetector method is an attribution method developed in the field of medical geography. Because the dependent variable and its related important factors have similar spatial or temporal distributions, this method has been widely used in economics, nature, society, and other fields in recent years, for spatial differentiation and mechanism research. Notably, compared with traditional measurement models, geographic detectors do not need to meet multiple assumptions, and the results are more accurate [46]. Our study uses the factor detection of the GeoDetector model to explore the spatial differentiation driving force of the sustainable development of urban human settlements. The calculation formula is as follows:

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} \quad (7)$$

where N is the number of samples in the study area, N_h is the number of samples in the area (category) h of the detection factor X, σ^2 is the total variance of Y in the study area (category), σ_h^2 is the variance of Y in the area (category) h of the detection factor X, and L is the number of regions (categories) of the detection factor X. The larger the value of q, the more significant the interpretation of X to Y, and vice versa.

3. Temporal and Spatial Differentiation of Sustainable Development of Urban Human Settlements in China

3.1. Development Trend

As seen in Figure 1, from 2000 to 2019, the overall level of sustainable development of urban human settlements in China steadily improved, portraying a continuous improvement trend. In 2000, the average level of sustainable development in urban human settlements was 0.25. By 2019, the score was 0.31, with a total growth rate of 23.61% and an average annual growth rate of 1.12%. The level of sustainable development of urban human settlements in China was specifically expressed as a gentle upward trend from 2000 to 2004, a short-term backward trend in 2005, and a significant increase in the growth rate of the development level from 2005 to 2010. In 2011, it experienced a short-term decline again and continued to rise from 2012–2016. The level of sustainable development continued to decline slightly in 2017–2018, and improved in 2019.

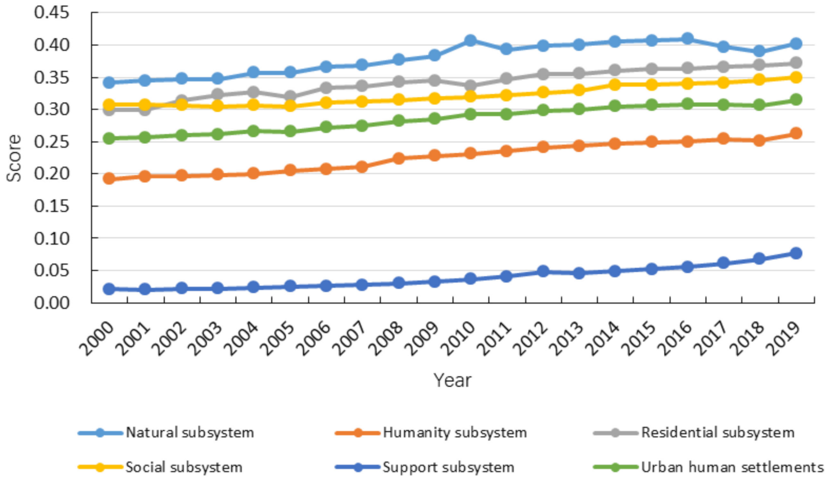


Figure 1. Trend chart of inter-annual sustainable development level of urban human settlements and subsystems in China.

3.2. *Temporal and Spatial Pattern*

The temporal and spatial evolution characteristics of the sustainable development level of urban human settlements include two aspects: The spatial distribution pattern and spatial correlation characteristics of the sustainable development of urban human settlements. In this study, we extracted data at five temporal points in 2000, 2005, 2010, 2015, and 2019, and used ArcGIS Jenks Natural Breaks to classify the sustainable development level of human settlements and subsystems of 285 prefecture-level cities into five levels: Low level of development, low to medium level of development, medium level of development, medium to high level of development, and high level of development. Using spatial autocorrelation, the spatial pattern characteristics and significance of the agglomeration space of the sustainable development level of urban human settlements in China were verified and visualized. The spatial distribution and LISA maps of the sustainable development level of urban human settlements in China were obtained.

3.2.1. Spatial Pattern of Sustainable Development Level of Urban Human Settlements Subsystems

1. Natural system

As seen in Figure 2, from 2000 to 2019, the spatial difference in the development level of the natural system of urban human settlements in China is relatively obvious. It shows that the overall spatial distribution characteristic is "high in the south and low in the north." The development level of the natural system in coastal cities is generally higher than that in inland cities. Overall, the areas with a relatively high level of development of the natural system of urban human settlements are concentrated in East China and Central South, and over time, high-value areas continue to gather in clusters to the southeast. From 2000 to 2019, the natural system scores of Shenzhen, Shanghai, Sanya, Hangzhou, and Xiamen were among the best. Shenzhen is at the forefront of the reform and opening up. Due to the high population and industrial density in the Pearl River Delta, the government attaches great importance to environmental governance and protection measures, and continuously strengthens investments in pollution control and governance. Air quality, anti-pollution ability, and resource conservation and utilization all have strong advantages. Per capita park green area and green coverage rate in Shanghai are both at the forefront of the country. Sanya and Xiamen have strong advantages in terms of air quality and the water environment. In recent years, under the guidance of the Double-Eight Strategy, Hangzhou has persisted in realizing the whole area of scenic spots and made every effort so that the construction of ecological civilization is in a leading position.

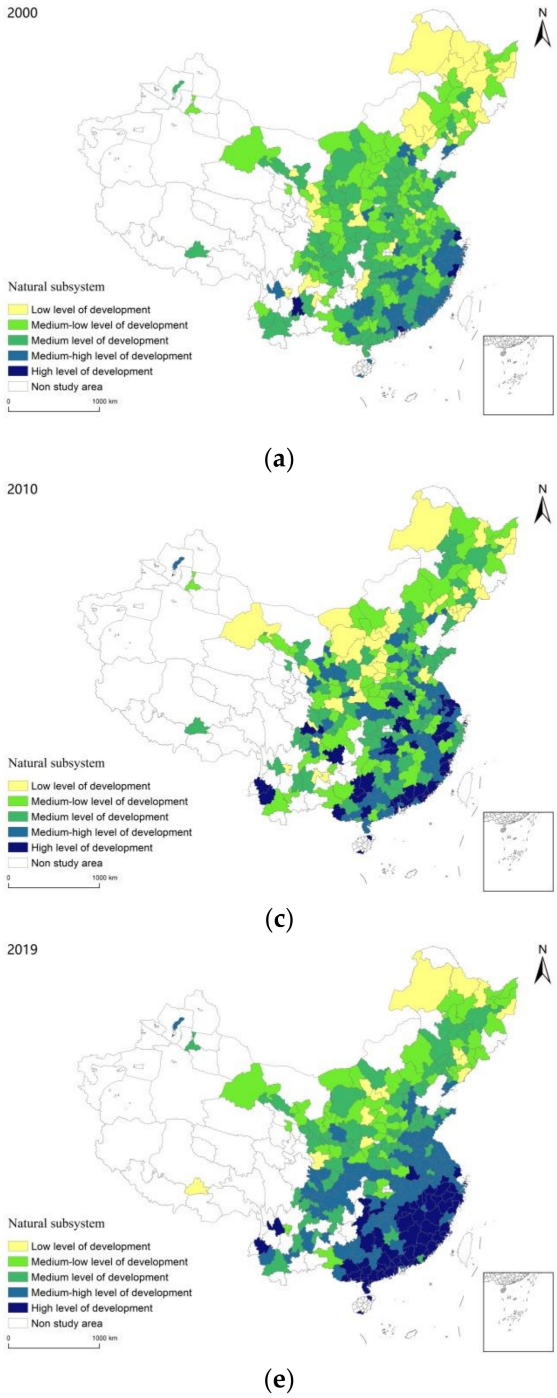


Figure 2. Spatial distribution map of the sustainable development level of the natural system of urban human settlements in China. (**a**) 2000; (**b**) 2005; (**c**) 2010; (**d**) 2015; and (**e**) 2019.

The prefecture-level cities with a low level of development of the natural system of urban human settlements were found to be concentrated in the Heilongjiang Province in the Northeast, the Shanxi Province, and the Inner Mongolia Autonomous Region in North China; areas with low development levels continue to gather in the northeast. The low level of development of the natural system of urban human settlements in Jixi, Heihe, Hulunbuir, Baishan, Tianshui, and Baiyin is mainly due to serious soil erosion, low greening, fragile ecological environment, relatively backward development, and unawareness of environmental protection.

2. Humanity system

As seen in Figure 3, between 2000 and 2019, the spatial difference in the development level of the humanity system of urban human settlements in China is relatively obvious, and the overall spatial pattern of “multi-level core-periphery” radial circle growth is prominent. From 2000 to 2019, Beijing, Hangzhou, Guangzhou, Changsha, and Wuhan were ranked high. Beijing is the capital of China, with a relatively balanced population structure. It is one of the regions with the richest educational resources. It has the largest number of well-known universities in the country, and the country’s largest scientific research and academic base, with strong scientific research and innovation capabilities. Educational resources in Hangzhou have continued to expand, and the strength of online education has increased in recent years. At the same time, Hangzhou is committed to building a “Binjiang Paradise Silicon Valley.” High-tech industries led by information, new medicines, environmental protection, and the application of new materials have strong momentum of development, and they have strong advantages in improving population quality. Wuhan ranks among the top in the country in terms of investment in scientific research funds and the number of patent authorizations. The developed high-tech industry has attracted a large number of young people. With a low degree of aging and a moderate population density, the population structure and quality show a positive development trend.

Notably, the prefecture-level cities with a low level of humanity system development in urban human settlements are concentrated in the Heilongjiang Province in the northeast and western regions, such as Yichun, Hegang, Shuangyashan, and Jixi in the Heilongjiang Province, Jinchang in the Gansu Province, Liaoyuan and Baishan in the Jilin Province, Wuhai in the Inner Mongolia Autonomous Region, Tongchuan in the Shaanxi Province, and Suining and Bazhong in the Sichuan Province. The main reason is that the development of these areas is relatively low; the population is constantly decreasing, education resources are scarce, and the ability of scientific research and innovation is also poor, which poses great difficulties in the overall improvement of population quality in the region.

3. Residential system

As seen in Figure 4, the development level of the residential system of urban human settlements in China presents a spatial pattern of expansion and growth from east to west, and the overall level gradually develops from a low-medium level to a medium-high level. In 2000, the high-value areas of residential system development were scattered in Kunming in the Yunnan Province, Langfang in the Hebei Province, and Zhuhai, Huizhou, and Foshan in the Guangdong Province. In 2005, a large number of areas with a high level of development in the residential system increased; this is especially true in the case of areas that developed into the Liaoning Province in East and Northeast China. During this period, the development level of the residential system in Sanya and Dalian improved significantly, mainly because these two coastal cities have good development with complete residential supporting facilities, relatively stable land prices and housing prices, and a moderate housing-price-to-income ratio. In 2009, the state carried out large-scale regulations and control of the real estate market. The real estate market tended to maintain stable and healthy development momentum. Housing security policies and supporting conditions have continuously improved. Therefore, during the period 2010–2019, the number of cities with high levels of development in the residential system continued to increase and were concentrated in the Beijing–Tianjin–Hebei urban agglomeration, the Jiangsu–Zhejiang–Shanghai area, the central part of the central and southern regions, and the southern part of the northeastern region.

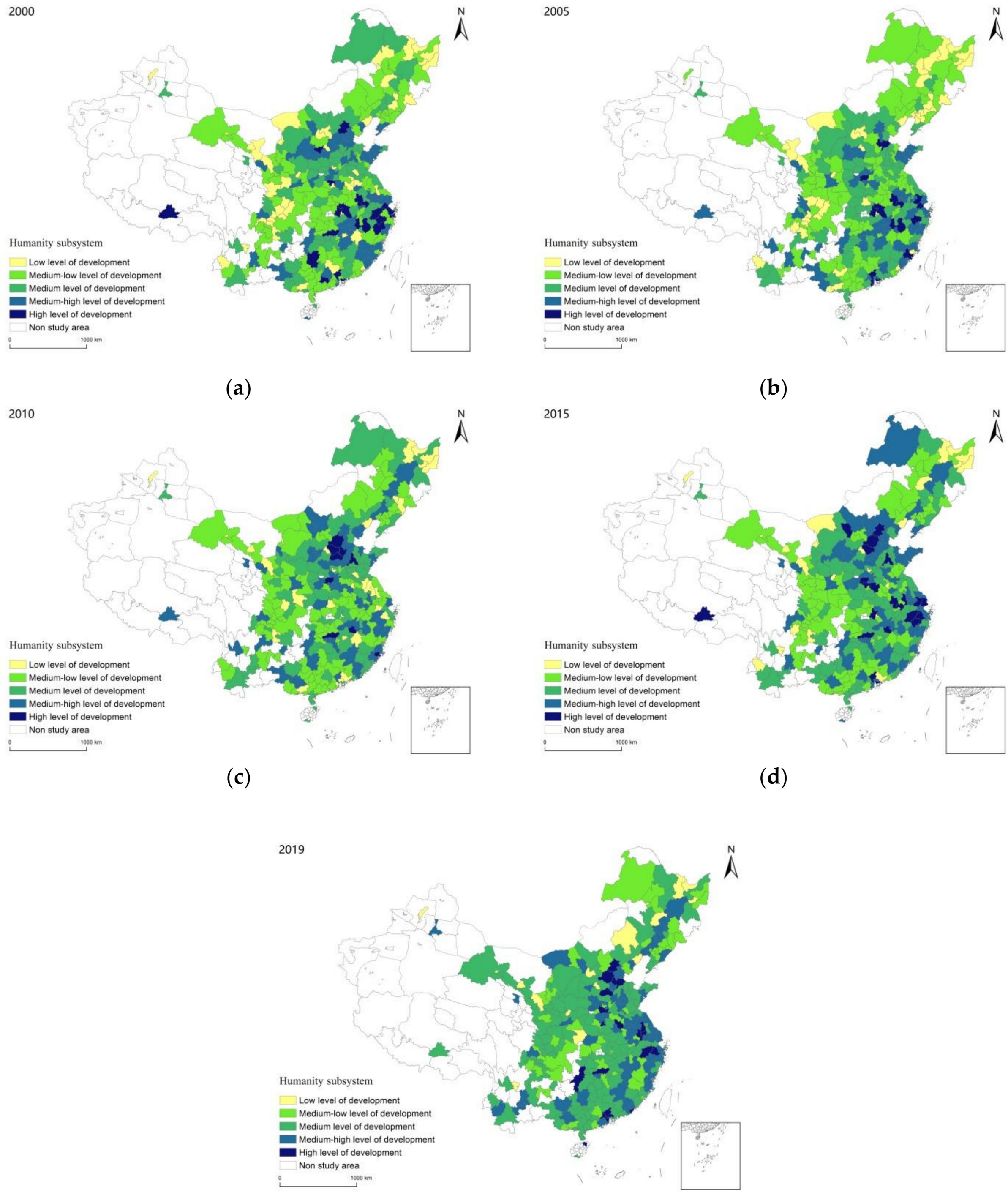
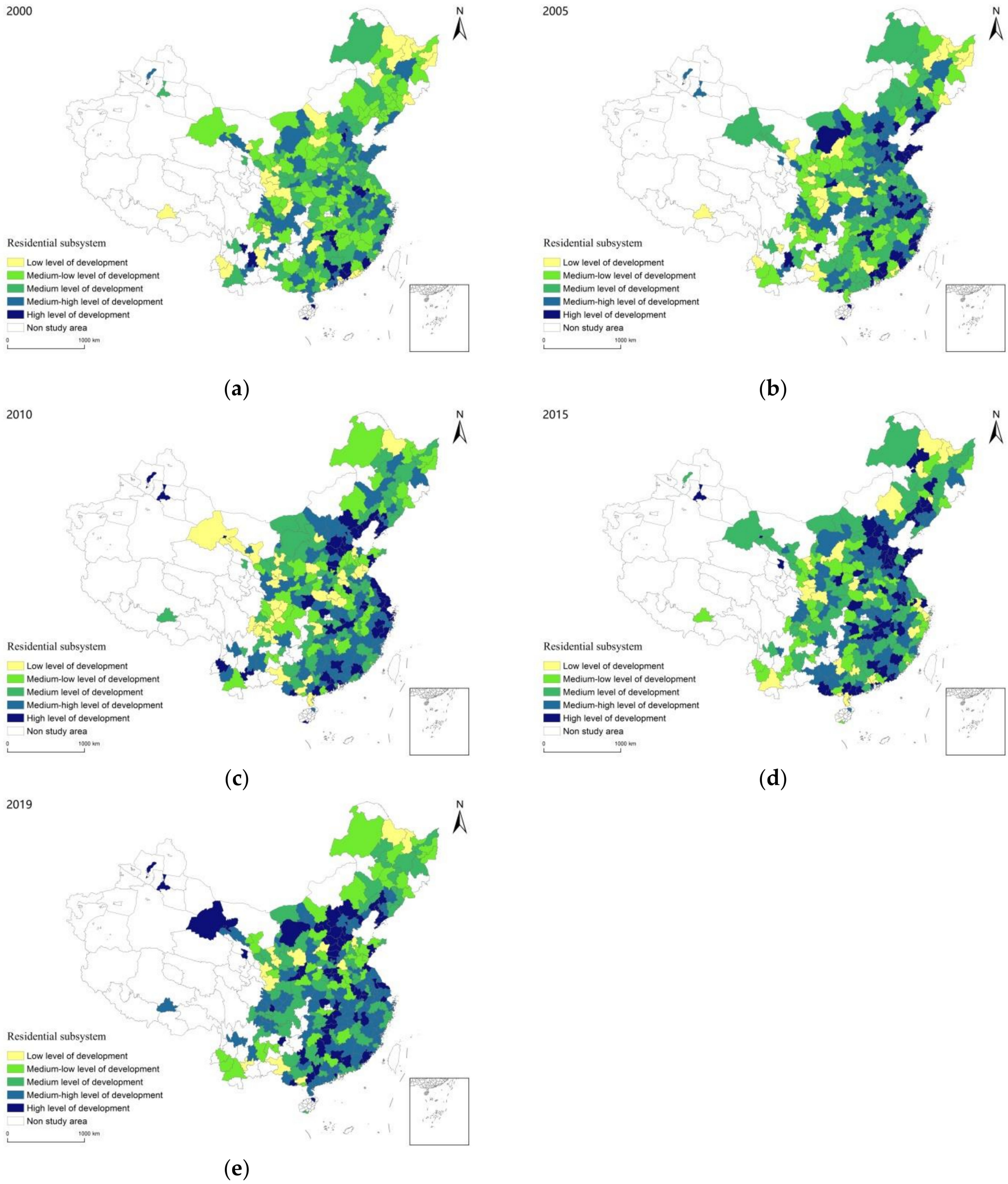


Figure 3. Spatial distribution map of the sustainable development level of the humanity system of urban human settlements in China. (**a**) 2000; (**b**) 2005; (**c**) 2010; (**d**) 2015; and (**e**) 2019.



(**a**) (**b**) (**c**) (**d**) (**e**)

Figure 4. Spatial distribution map of the sustainable development level of the residential system of urban human settlements in China. (**a**) 2000; (**b**) 2005; (**c**) 2010; (**d**) 2015; and (**e**) 2019.

Notably, the prefecture-level cities with a low level of development of the urban human settlements residential system are concentrated in the Heilongjiang Province, the Gansu Province, and the Ningxia Hui Autonomous Region. Hegang, Heihe, and Qitaihe in the Heilongjiang Province, Tianshui, Jinchang, and Longnan in Gansu, and Guyuan and Zhongwei in the Ningxia Hui Autonomous Region have relatively low development, the per capita investment in real estate housing is relatively small, and the housing supporting infrastructure is not complete, resulting in a low level of development of the residential system.

4. Social system

As shown in Figure 5, from 2000 to 2019, the development level of the social system of urban human settlements in China shows a distribution characteristic of "high in the east and low in the west." Specifically, in 2000, cities with high levels of social systems were mainly concentrated in Heilongjiang and Liaoning in the Northeast and Jiangsu and Fujian in East China. Since the founding of New China, the Northeast, as a hotspot of China's industrialization, has made great contributions to China's economic development. Cities such as Dalian, Shenyang, and Harbin took the lead in focusing on import and export trade and strengthened the development of international cities, and together with the abundant material resources, they have a relatively high level of social development. From 2005 to 2019, the number of cities with middle–high and high development levels in the social system increased significantly. The Beijing–Tianjin–Hebei urban agglomeration, East China, and central and southern regions continue to affect the surrounding areas, and high-value areas radiate to the surrounding area. In particular, Shanghai, Shenzhen, Guangzhou, Hangzhou, and Suzhou in the eastern coastal areas, Changsha in the Hunan Province, and Ordos and Hulunbuir in the Inner Mongolia Autonomous Region have made significant progress, while the level of social system development in the Northeast has been declining. The reason is that the Northeast is deeply influenced by the concept of the planned economic system, and the ideological concepts are rigid, which has resulted in the industrial structure of the Northeast being unable to keep up with the pace of development in the country. At the same time, the aging population and loss of talent in the Northeast have led to a continuous decline in the development of the northeastern social system. The advantages of coastal cities, such as Shenzhen, Guangzhou, Shanghai, Suzhou, and Hangzhou are becoming increasingly obvious. The gross domestic product (GDP) and residents' income have grown steadily, the regional industrial structure is reasonable, the foreign economy is active, material resources such as grain and aquatic products are abundant, and the level of social system development is constantly improving.

Cities with a low level of social system development are concentrated in the southern part of the Sichuan Province and most areas of the Gansu Province. For example, Dazhou, Suining, Zhangye, and Wuwei are far from China's core economic areas. Inconvenient transportation in these regions has caused difficulties in foreign exchange. In this region, the industries are relatively poor, the structure is irrational, and the ability to integrate resources is weak. All of these have caused the city's economic aggregate, per capita level, and economic development rate to remain at the middle–low level.

5. Support system

As seen in Figure 6, from 2000 to 2019, the spatial differentiation of the development level of China's urban human settlement support system is not obvious. The overall spatial pattern shows uneven growth, with high-value areas scattered in the Beijing–Tianjin–Hebei urban agglomeration, East China, and Central South regions. From 2000 to 2010, the number of cities with a high level of development in China's urban human settlement support system was relatively small, mainly concentrated in the Beijing–Tianjin–Hebei urban agglomeration and the Guangdong Province in the central and southern regions. From 2015 to 2019, the number of cities with a high level of development in China's urban human settlement support system gradually increased, and the high-value areas radiated outward. In particular, Hubei and Zhejiang provinces have made significant progress. Specifically, Beijing, as the capital of China, focuses on the leading role of infrastructure in the process of urban construction. Infrastructure, such as medical resources, public transportation, and Internet communications, has great advantages, and the per capita public service resources are also abundant. Therefore, the level of development of the support system is relatively high, which has also driven the surrounding cities of Hengshui, Baoding, and Xingtai. Furthermore, infrastructure investment in Jiaxing, Jinhua, Wenzhou, Shenzhen, Dongguan, and other cities has increased rapidly, and the communication infrastructure is in the leading position in the country. In recent years, efforts have been made to implement digital infrastructure operations and create a very modern infrastructure system, which has led to the development of a support system. Provincial capitals, such as Hefei, Wuhan, and Changsha, have a complete infrastructure and abundant per capita public service resources, which causes the system to develop evenly with significant progress.

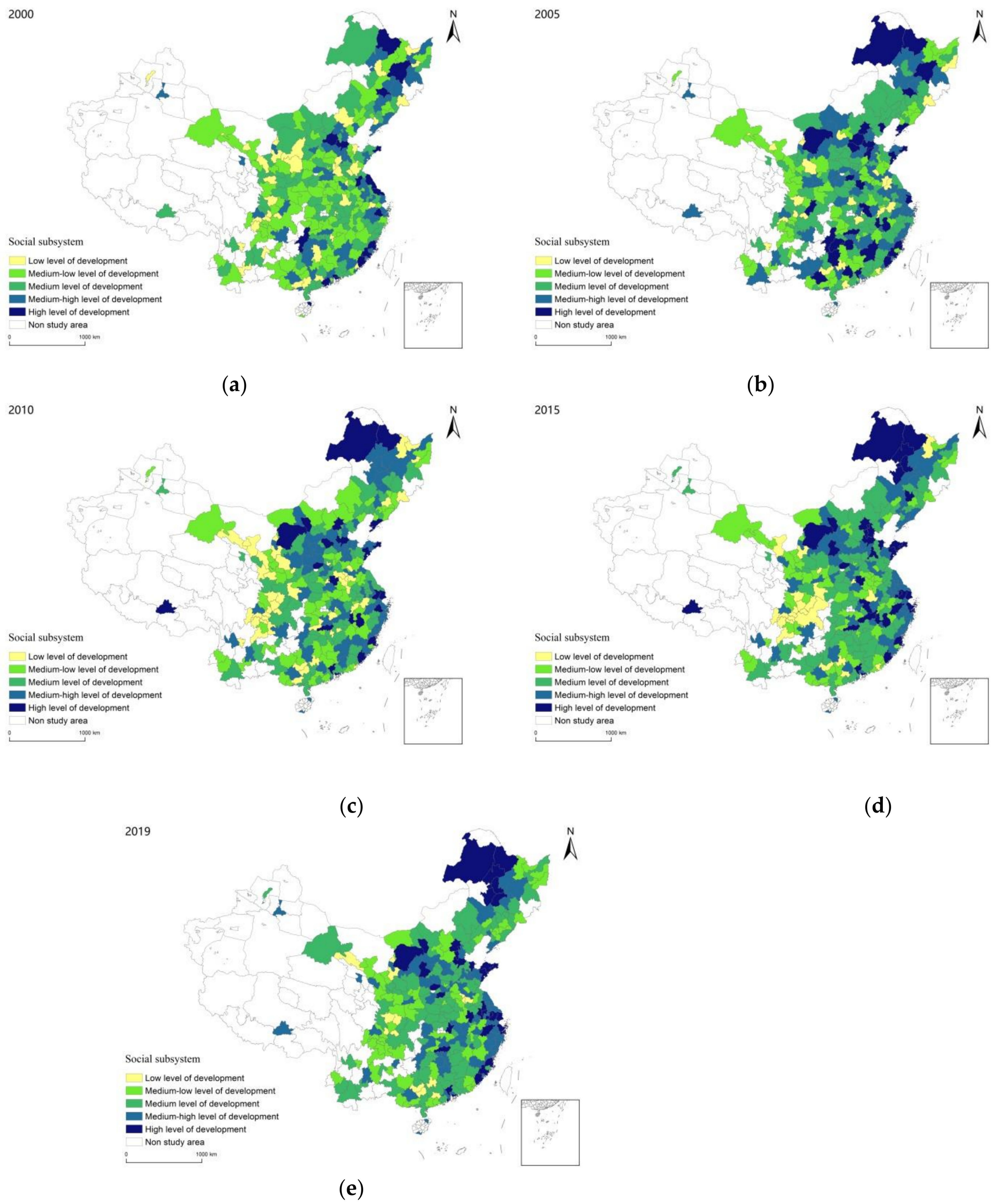


Figure 5. Spatial distribution map of the sustainable development level of the social system of urban human settlements in China. (**a**) 2000; (**b**) 2005; (**c**) 2010; (**d**) 2015; (**e**) 2019.

Notably, cities with a low level of urban human settlements support systems are concentrated in the eastern parts of the Henan, Guangxi, and Gansu provinces and the northeastern part of the Sichuan Province. Some regions, such as Guigang, Hezhou, Suining, Ziyang, Shangqiu, Xinyang, and Longnan, have underdeveloped transportation, relatively backward medical resources, low quantity and quality of public services, and poor communication infrastructure, which is far from the national average.

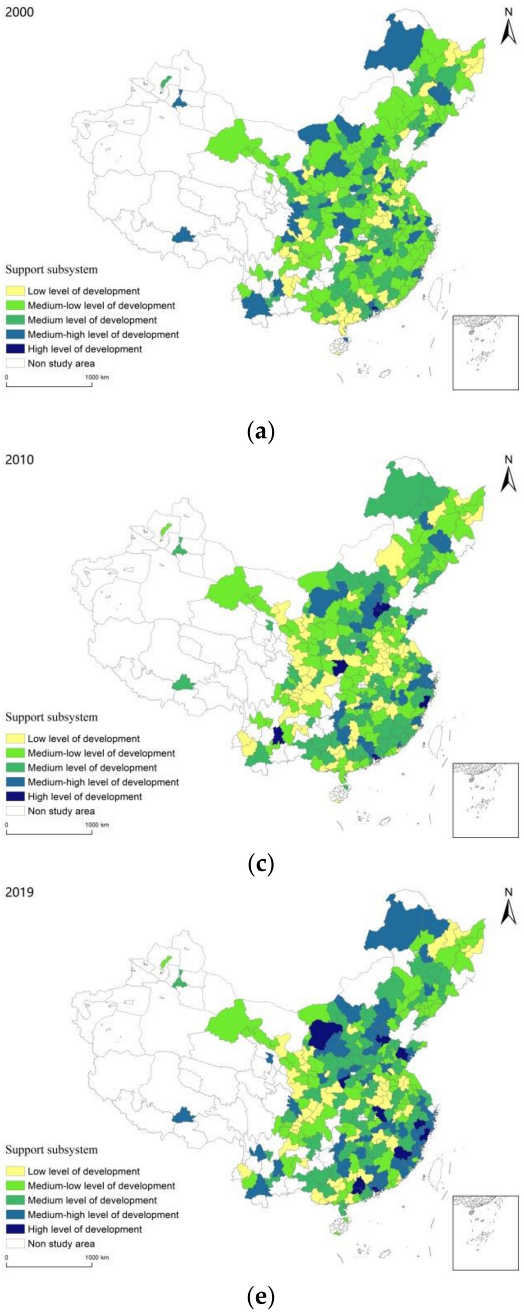


Figure 6. Spatial distribution map of the sustainable development level of the support system of urban human settlements in China. (**a**) 2000; (**b**) 2005; (**c**) 2010; (**d**) 2015; and (**e**) 2019.

3.2.2. Spatial Pattern of Sustainable Development Level of Urban Human Settlements

As seen in Figure 7 and Tables 2 and 3, between 2000 and 2019, the spatial difference in the level of sustainable development of urban human settlements in China is relatively obvious. The overall performance is spreading and growing from east to west, portraying the spatial distribution characteristics of "high in the east and low in the west; high in the south, and low in the north." On the whole, prefecture-level cities with a high level of sustainable development of urban human settlements are concentrated in the coastal areas of East China and Central and Southern China regions, as well as the Beijing–Tianjin–Hebei urban agglomeration in North China. High-value areas continue to gather to the southeast, and prefecture-level cities with a low level of sustainable development are concentrated in the northeastern and inland cities in Northwest and North China.

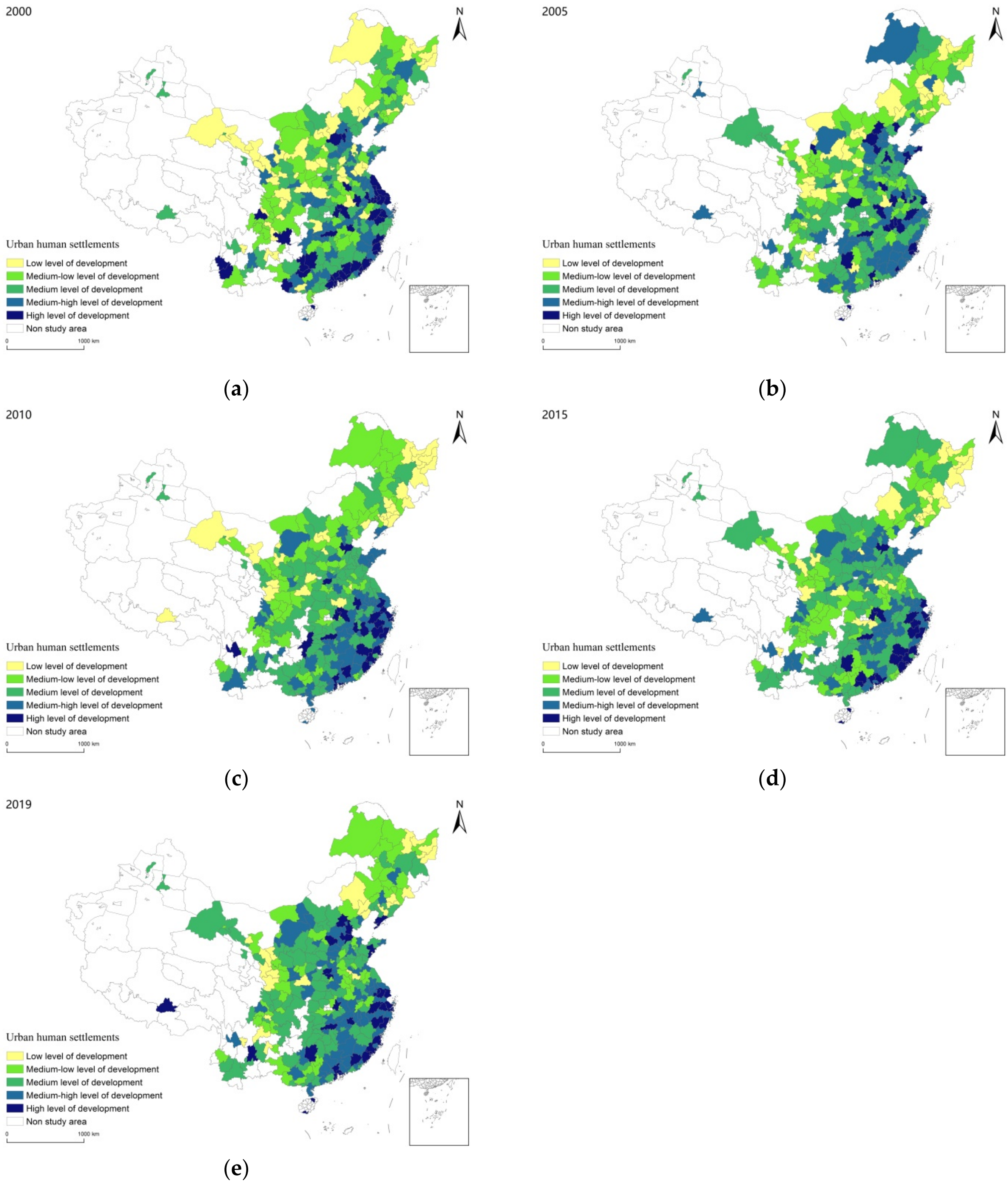


Figure 7. Spatial distribution map of the sustainable development level of urban human settlements in China. (**a**) 2000; (**b**) 2005; (**c**) 2010; (**d**) 2015; and (**e**) 2019.

Table 2. The top ten cities in China's urban human settlements development level and their scores.

Ranking	2000		2005		2010		2015		2019	
	Cities	Scores	Cities	Scores	Cities	Scores	Cities	Scores	Cities	Scores
1	Shenzhen	0.330	Shenzhen	0.310	Shenzhen	0.387	Shenzhen	0.361	Shenzhen	0.382
2	Guangzhou	0.313	Hangzhou	0.305	Hangzhou	0.372	Guangzhou	0.354	Shanghai	0.380
3	Hangzhou	0.306	Changsha	0.304	Guangzhou	0.370	Shanghai	0.354	Beijing	0.378
4	Shanghai	0.303	Shanghai	0.303	Suzhou	0.370	Hangzhou	0.353	Hangzhou	0.376
5	Changsha	0.300	Beijing	0.301	Changsha	0.355	Changsha	0.346	Guangzhou	0.371
6	Suzhou	0.300	Guangzhou	0.300	Wuhan	0.342	Wuhan	0.346	Changsha	0.369
7	Nanjing	0.300	Hefei	0.299	Hefei	0.340	Fuzhou	0.345	Kunming	0.368
8	Fuzhou	0.298	Nanjing	0.298	Zhuhai	0.340	Sanya	0.345	Suzhou	0.366
9	Xiamen	0.297	Sanya	0.298	Fuzhou	0.339	Guilin	0.345	Qingdao	0.363
10	Wuhan	0.295	Fuzhou	0.297	Zhengzhou	0.336	Xiamen	0.343	Sanya	0.363

Table 3. The bottom ten cities in China's urban human settlements development level and their scores.

Ranking	2000		2005		2010		2015		2019	
	Cities	Scores	Cities	Scores	Cities	Scores	Cities	Scores	Cities	Scores
1	Yichun	0.196	Baishan	0.220	Yichun	0.235	Baishan	0.253	Yichun	0.247
2	Baishan	0.197	Yichun	0.220	Jixi	0.243	Yichun	0.259	Baiyin	0.253
3	Hegang	0.210	Hegang	0.224	Fushun	0.243	Qitaihe	0.260	Qitaihe	0.259
4	Qitaihe	0.211	Longnan	0.225	Hegang	0.247	Jixi	0.261	Baishan	0.261
5	Shuozhou	0.213	Shuozhou	0.227	Longnan	0.247	Hegang	0.265	Hegang	0.262
6	Jixi	0.213	Baiyin	0.230	Baishan	0.251	Longnan	0.265	Jixi	0.267
7	Bazhong	0.214	Liaoyuan	0.230	Tianshui	0.252	Fushun	0.265	Dingxi	0.268
8	Tianshui	0.214	Jixi	0.232	Shuozhou	0.253	Liaoyuan	0.267	Zhongwei	0.268
9	Liupanshui	0.215	Tianshui	0.233	Qitaihe	0.253	Baiyin	0.269	Longnan	0.270
10	Tongchuan	0.215	Chaoyang	0.237	Wuwei	0.254	Wuzhong	0.270	Tianshui	0.273

Specifically, Shenzhen ranked first in the level of sustainable development of urban human settlements in China from 2000 to 2019, and Hangzhou, Changsha, Guangzhou, and Shanghai have repeatedly ranked among the top five. Shenzhen is located in the southern coastal area of Guangdong Province. It was fully urbanized in 2004 and became China's first city without a rural area. From a small fishing village to an innovative, inclusive, and dynamic modern international city, Shenzhen has developed rapidly and solidly: A good living environment and high level of greening, high level of education and strong scientific research ability, a developed transportation and road network, complete infrastructure per capita, and a high level of public services are observed, and the level of industrialization closely follows the level of urbanization. While the economy is developing rapidly, it also provides employment opportunities and social security for a large number of people who have moved into Shenzhen; therefore, the urban human settlements develop in a comprehensive, balanced, and stable manner. Hangzhou is the economic, cultural, scientific, and educational center of Zhejiang Province. It is also a well-known tourist city in the country, and its ecological civilization construction is in a leading position in China; high-tech industries dominated by new pharmaceuticals and environmental protection are also advantages of Hangzhou; owing to the rapid development of private enterprises, abundant resources, and high living quality of residents, Hangzhou's comprehensive strength of urban human settlements is good. Changsha is located in the eastern part of Hunan Province. It is an important central city in the middle reaches of the Yangtze River in China and is an important transportation hub of the country. In this city, the climate is mild, and the air quality has improved significantly; owing to the automobile, culture, and equipment manufacturing being its key industries, the city has made a great contribution to the development of the country's economy. Notably, high-tech industries, such as super hybrid rice and Beidou satellite, have brought together talent, and the sustainable development of urban human settlements has strong momentum. Guangzhou is located in the south-central part of Guangdong Province; it has a superior geographical location and is regarded as the southern gate of China to the world. It has a long cultural history, strong political and cultural education and medical resources as advantages, high quality of the urban garden landscape, and good ecological environment. Additionally, the region has a strong economic foundation and a vigorously developing industrial sector, and the development of import and export trade, along with the modern service industry, has also contributed to the sustainable development level of urban human settlements in this region.

During the research period, among the bottom ten prefecture-level cities in terms of the sustainable development level of urban human settlements, Yichun, Hegang, Qitaihe, Jixi, Baishan, and Tianshui have shown improvements in their human settlements; however, compared to other cities, they are still in a backward position. Yichun City is located in the northeast of the Heilongjiang Province. It is a typical forestry resource-based city, and the development of its urban human settlements is very slow. This is because forestry is the main industry in Yichun, and its economic development structure is relatively simple. Due to environmental problems, such as desertification and soil erosion caused by excessive deforestation, residents' productivity and life have become severely challenged, and greater employment pressure, weak social security capabilities, and underdeveloped infrastructure have caused the population to continue to move out of these regions. All these factors have led to a low level of sustainable development of urban human settlements in Yichun and a slower rate of improvement. Hegang, Jixi, and Qitaihe are located in the northeast of Heilongjiang Province. They are important industrial and resource-based cities dominated by coal mines. The gradual depletion of energy has caused the urban economy to stagnate, the ecological environment is extremely problematic, and population loss is accelerating, resulting in Hegang becoming an empty city. Baishan is located on the west side of Changbai Mountain in Jilin Province. It is rich in natural resources, such as minerals and forestry. It has good water quality and high forest coverage, but its economic development is relatively backward, the quality of urban infrastructure and public services is low, and the overall level of urban human settlements is poor. In recent years, through economic transformation, the vigorous development of the tourism industry, and adherence to the method of green ecological development, the level of sustainable development of urban human settlements in this region has improved. Tianshui is located in the southeastern part of Gansu Province. Because it has been stuck in the traditional economic development model, its total economic volume, per capita economic level, and economic growth rate are all in a backward position. Correspondingly, the construction of urban supporting facilities has stagnated, and population loss has been serious, which has resulted in a low sustainable development level of urban human settlements.

3.2.3. Spatial Correlation Pattern of Sustainable Development Level of Urban Human Settlements

This study uses spatial autocorrelation to verify the spatial pattern characteristics and significance of the agglomeration space of the sustainable development level of urban human settlements in China. Table 4 shows that the Moran's I index of sustainable development of urban human settlements in China indicated a fluctuating decline, and the p-values were all 0 in the five frames of 2000, 2005, 2010, 2015, and 2019. This shows that the sustainable development level of urban human settlements in China's 285 prefecture-level cities presents a relatively significant and stable distribution of high and low spatial agglomeration, and the spatial agglomeration tends to weaken during the study period.

Table 4. Moran's I of the sustainable development level of urban human settlements in China.

Year	2000	2005	2010	2015	2019
Moran's I	0.2092	0.1595	0.2778	0.1819	0.1740
Z score	27.0187	20.6973	35.7311	23.5517	22.5954
P value	0.0000	0.0000	0.0000	0.0000	0.0000

As seen in Figure 8, the HH agglomeration areas for sustainable development of urban human settlements are mainly concentrated in East China and Central South, especially in the eastern coastal cities; the LL agglomeration areas are mainly distributed in the northeast area and underdeveloped cities in the west, and the scope of the LL agglomeration area in the west is significantly reduced. Specifically, the HH agglomeration areas for the sustainable development of urban human settlements in 2000 were mainly distributed in Shanghai, Nanjing, and Wuxi in the Jiangsu Province, Hangzhou and Ningbo in the Zhejiang Province, Hefei, Wuhu, and Ma'anshan in the Anhui Province, Putian and Xiamen in the Fujian Province, Nanchang and Jingdezhen in the Jiangxi Province, Wuhan and Huanggang in the Hubei Province, Changsha and Xiangtan in the Hunan Province, Guangzhou and Shaoguan in the Guangdong Province, Liuzhou and Guilin in the Guangxi Zhuang Autonomous Region, and Haikou and Sanya in the Hainan Province. The LL gathering area is mainly concentrated in the northern LL gathering area composed of Zhangjiakou in the Hebei Province, Datong and Yangquan in the Shanxi Province, Baotou and Wuhai in the Inner Mongolia Autonomous Region, Benxi in the Liaoning Province, Jilin and Baishan in the Jilin Province, and Jixi and Hegang in the Heilongjiang Province. The LL gathering area is composed of Sanmenxia in the Henan Province, Chongqing City, Panzhihua, and Luzhou in the Sichuan Province, Zhaotong in the Yunnan Province, Tongchuan and Weinan in the Shanxi Province, Lanzhou and Jinchang in the Gansu Province, and Shizuishan and Wuzhong in the Ningxia Hui Autonomous Region. In 2005, the HH cluster area decreased. Cangzhou and Hengshui in the Hebei Province, as well as Jinan, Qingdao, and other cities in the Shandong Province improved the sustainable development level of human settlements and developed into new HH agglomeration areas. The center of gravity of the LL cluster in the north shifted eastward; the LL cluster in the northeast expanded, while the LL cluster in the west shrunk, which was mainly reflected in the narrowing of the scope of the LL cluster in the Sichuan Province. In 2010, the HH agglomeration areas in eastern China, such as Zhejiang and Jiangxi, increased and showed a continuous clustering distribution, reflecting the positive promotion effect of East China. The scope of LL clusters in North China and Northeast China expanded and showed a clustered distribution pattern. In 2015, the agglomeration pattern of the HH agglomeration area in the east became clearer. The spatial scope of LL agglomeration areas has currently shrunk, mainly because the LL agglomeration areas in North China have almost disappeared. At the same time, the LL agglomeration areas in the Shaanxi Province also decreased. In 2019, the spatial distribution of HH agglomeration areas changed slightly. While the urban human settlements are developing steadily, the radiation and driving role of the eastern coastal cities should be strengthened; the northern LL area extends north again, and the western LL area extends south again. We observed that the weak interaction between Northeast China and Western China is still strong, and the sustainable development level of urban human settlements needs to be further improved in these regions.

3.3. Development Model

Based on the above detailed analysis of the sustainable development level of urban human settlements in 285 prefecture-level cities in China, the changes in the development level of each year were summarized and classified into four categories and ten sub-categories (Figure 9). The first consisted of the human settlements with strong sustainability, including two sub-categories "H" and "M"; the second consisted of human settlements with medium sustainability, including four sub-categories "H-M/L-H," "M-H/L-M," "M-H", and "L-H/M." The third consisted of human settlements with weak sustainability, including two sub-categories "H-M/L" and "M-L"; the fourth consisted of unsustainable human settlements, including two subcategories "L" and "L-H/M-L." Note that H represents the high and medium-high level of sustainable development of urban human settlements, M represents the medium development level, and L represents the low and medium-low development levels.

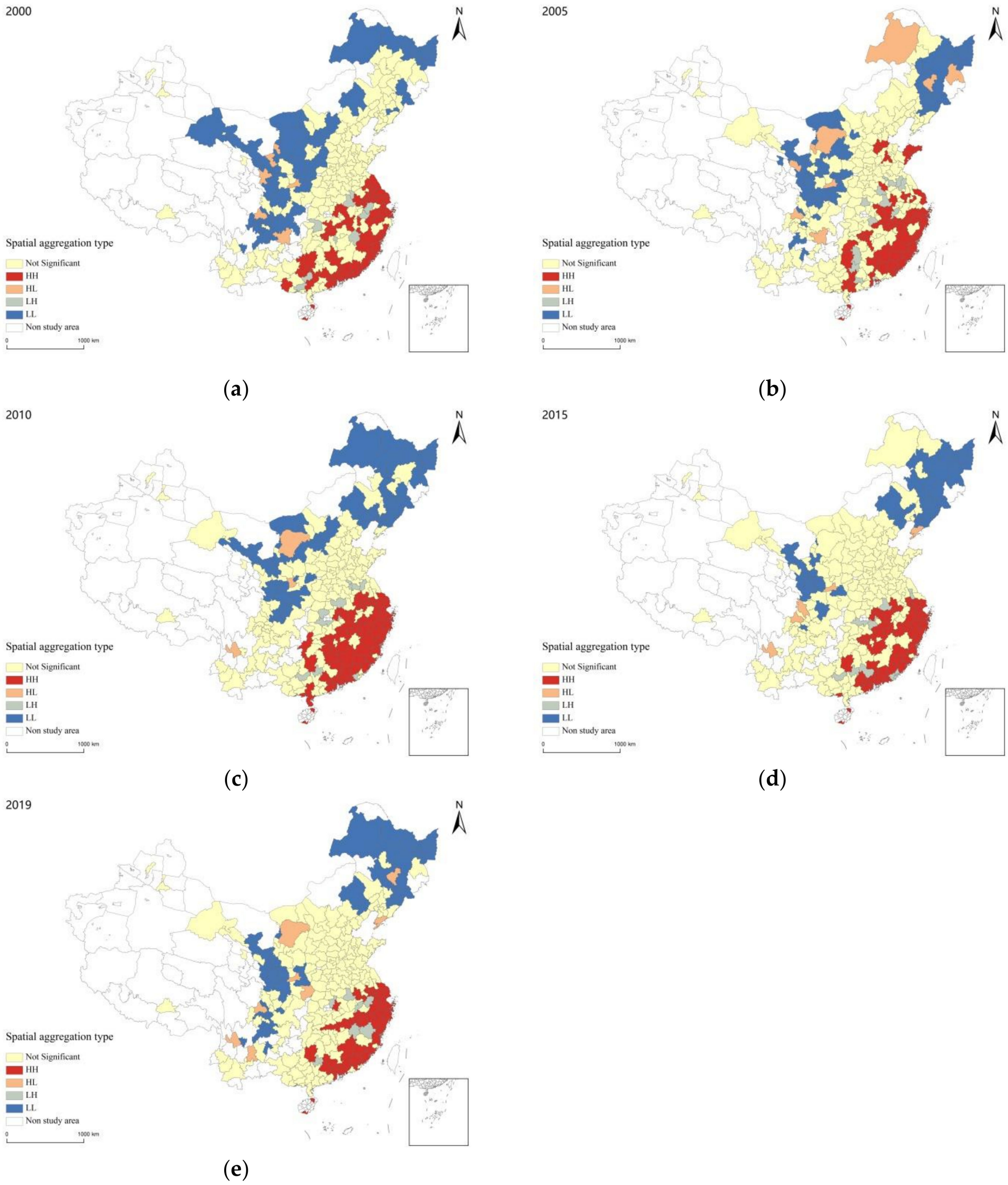


Figure 8. Spatial distribution map of the local indicator of spatial association (LISA) of the sustainable development level of urban human settlements in China. (**a**) 2000; (**b**) 2005; (**c**) 2010; (**d**) 2015; and (**e**) 2019.

From the perspective of the sustainable development model of urban human settlements, the "H" and "M" types are the optimal development models. These two types of cities have a relatively high and stable level of development in human settlements and have strong sustainable development capabilities. A total of 47 cities belong to these two types, accounting for 16% of the study area. Most of them are southeast coastal cities and provincial capitals, mainly distributed in East China and Central South, such as Shanghai, Nanjing, Hangzhou, Qingdao, Zhengzhou, Changsha, Guangzhou, Nanning, and Sanya; the living environment of cities, such as Beijing, Dalian, Chengdu, Kunming, and Karamay also have a high level of development, with outstanding advantages in sustainable development. The "H-M/L-H" and "M-H/L-M" types of development models indicate the fluctuation phenomenon of falling or rising during the development of urban human settlements. The unstable development situation of these two types includes 31 and 26 cities, respectively, accounting for 20% of the total. The distribution is relatively scattered, mainly in the third and fourth-tier cities, such as Langfang, Jinzhou, Nantong, Wuhu, and Urumqi. These two types of cities should explore a path suitable for their own development as soon as possible to avoid weakening the sustainability of the development of urban human settlements in the process of repeated adjustments. The development level of human settlements in "M-H" and "L-H/M" cities is obviously improving from low and medium development level to medium and high. There are 28 and 47 cities in these two types, respectively, with the highest proportion reaching 26%. This shows that the sustainable development level of urban human settlements in China is constantly improving. Most of them are inland cities with a wide range of distribution, such as Shijiazhuang, Taiyuan, Hohhot, Shenyang, Kaifeng, Chongqing, and Yan'an. The Shanxi Province, Jiangxi Province, Henan Province, and Sichuan Province also performed prominently. Notably, the development level of "H-M/L" and "M-L" types of urban human settlements has declined, including a total of 42 cities, mainly distributed in the central parts of the Northeast region and East China, along with the central and southern China region, including Harbin, Fushun, Ma'anshan, Xiaogan, Yiyang, and Hezhou. This development model indicates that bottlenecks have been encountered in the development of urban human settlements, and timely and effective regulation has not been carried out, resulting in a lack of coordination within the system and restricted orderly development. Therefore, key issues should be understood to deepen reforms as soon as possible and restore good development momentum. The "L" and "L-H/M-L" types of development models are the worst, including 64 cities, accounting for 22% of the research subjects. The cities of these types are mainly inland, distributed in the western part of North China, northeastern China, and the eastern part of the western region, such as Yangquan, Hulunbuir, Chaoyang, Shuangyashan, Shangqiu, Bazhong, Tongchuan, Longnan, and Guyuan. The quality of human settlements in these cities has been in a poor state of development for a long time. Even if there was progress during the research period, it still has a low level of development, and basically, does not have the capacity for sustainable development. Thus, in these regions, urban human settlements can be effectively managed and sustainable development can be gradually realized only by deep learning from failures, drawing on the mature development model of the obvious improvement of urban human settlements, and implementing a targeted and reasonable development path.

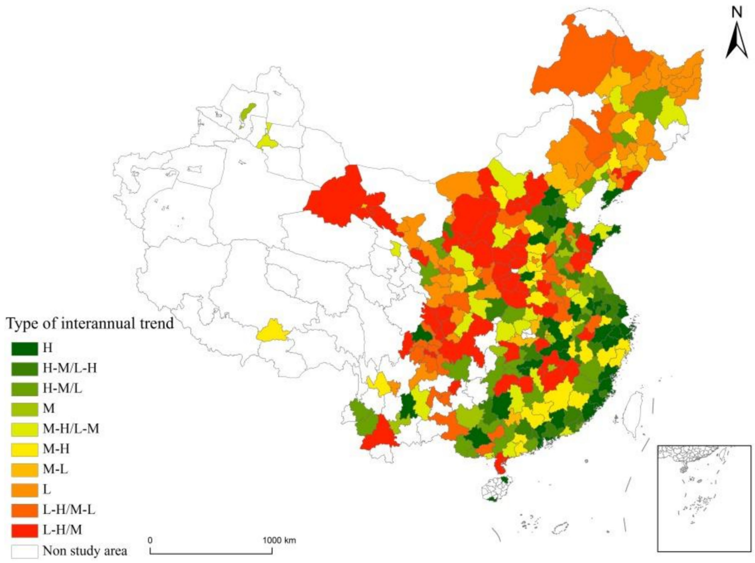


Figure 9. Spatial distribution map of the sustainable development model of urban human settlements in China.

4. Driving Forces for Sustainable Development of Urban Human Settlements in China

In this section, GeoDetector is used to detect the main factors and decisive forces that affect the spatial differentiation of the sustainable development level of urban human settlements in different periods. To improve the accuracy of the results, the top 20 indicators with a large coefficient of variation were selected as the main detection factors. SPSS was used to discretize the panel data of the selected indicators, and the indicators were converted into different types. The strength values (q values) of each indicator force were obtained using GeoDetector, and their significance was tested (Table 5).

Table 5. The determining power of driving factors of the sustainable development level of urban human settlements in China.

	2000		2005		2010		2015		2019	
	Q-Value	**Ranking**	**Q-Value**	**Ranking**	**Q-Value**	**Ranking**	**Q-Value**	**Ranking**	**Q-Value**	**Ranking**
X3	0.352 ***	1	0.271 ***	5	0.365 ***	4	0.194 ***	13	0.315 ***	9
X5	0.290 ***	4	0.168 ***	10	0.100 ***	15	0.114 ***	15	0.227 ***	12
X8	0.149 ***	12	0.122 ***	13	0.052 **	17	0.041 *	20	0.059 **	18
X15	0.262 ***	6	0.240 ***	7	0.295 ***	7	0.317 ***	4	0.322 ***	8
X17	0.256 ***	7	0.246 ***	6	0.200 ***	11	0.413 ***	3	0.428 ***	4
X18	0.024 *	20	0.070 *	17	0.434 ***	3	0.294 ***	6	0.517 ***	2
X20	0.092 **	16	0.073 **	16	0.064 ***	16	0.067 **	16	0.084 ***	17
X21	0.228 ***	8	0.371 ***	1	0.534 ***	2	0.458 ***	1	0.433 ***	3
X22	0.214 ***	10	0.160 ***	11	0.180 ***	12	0.201 ***	10	0.151 ***	13
X25	0.338 ***	2	0.329 ***	2	0.583 ***	1	0.438 ***	2	0.572 ***	1
X26	0.326 ***	3	0.280 ***	4	0.332 ***	5	0.196 ***	12	0.292 ***	10
X28	0.055 *	18	0.031	20	0.043 *	19	0.057 *	19	0.039 **	20
X30	0.143 ***	13	0.172 ***	9	0.304 ***	6	0.228 ***	9	0.387 ***	6
X31	0.073 **	17	0.063 *	18	0.048 *	18	0.067 *	17	0.090 ***	16
X33	0.226 ***	9	0.231 ***	8	0.136 ***	14	0.128 ***	14	0.125 ***	14
X34	0.136 ***	14	0.079 **	15	0.229 ***	9	0.291 ***	7	0.254 ***	11
X35	0.043 *	19	0.051 *	19	0.015	20	0.061 *	18	0.044 *	19
X37	0.117 ***	15	0.114 ***	14	0.222 ***	10	0.197 ***	11	0.114 ***	15
X38	0.266 ***	5	0.319 ***	3	0.263 ***	8	0.306 ***	5	0.362 ***	7
X40	0.154 ***	11	0.149 ***	12	0.157 ***	13	0.278 ***	8	0.409 ***	5

Note that ***, **, and * represent the significance of the factor at 1%, 5%, and 10%, respectively.

From the perspective of time series, the dominant driving factors of the sustainable development of urban human settlements in China have only experienced minimal changes, and there are certain differences in their decisive power. The driving factors with the strongest explanatory power for the sustainable development of the urban human settlements in China in 2000 were $PM_{2.5}$ concentration, per capita GDP, proportion of tertiary industry in GDP, per capita park green area, and Internet penetration rate. The core driving factors in 2005 were the ratio of house price to income, GDP per capita, Internet penetration rate, proportion of tertiary industry in GDP, and $PM_{2.5}$ concentration. In 2010, the core driving factors were per capita GDP, housing-price-to-income ratio, R&D investment intensity, $PM_{2.5}$ concentration, and proportion of tertiary industry in GDP. In 2015, the core driving factors were the ratio of housing prices to income, GDP per capita, share of education expenditure, number of college students per 10,000 people, and Internet penetration rate. In 2019, the core driving factors were per capita GDP, R&D investment intensity, housing-price-to-income ratio, education expenditure ratio, and number of buses owned by 10,000 people. As shown in Table 5, the per capita GDP, housing-price-to-income ratio, Internet penetration rate, education expenditure ratio, R&D investment intensity, and $PM_{2.5}$ concentration are the leading factors affecting the sustainable development of urban human settlements, and they have different effects in different aspects.

1. Gross domestic product (GDP) per capita

GDP per capita reflects the economic level of urban social development. Economic development is the basic requirement for promoting the sound and steady development of urban human settlements, and it is also an important indicator for measuring the living standards of urban residents. From 2000 to 2019, the per capita GDP factor had a relatively stable impact on the sustainable development of urban human settlements. Its decisive power (q) fluctuated from 0.338 in 2000 to 0.572 in 2019. In February 2021, China achieved complete poverty alleviation, but economic development remained unbalanced. The economic development of the eastern coastal cities was better than that of the western inland cities. This difference in economic levels between cities does not only affect the differences in urban construction, thereby affecting the improvement of the ecological environment, living conditions, and public services, but also the differences in residents' income levels, which in turn, affects the urban residents' well-being. Therefore, there is a strong correlation between the per capita GDP and the spatial pattern of the sustainable development level of urban human settlements.

2. Housing-price-to-income ratio

Housing provides the foundation for urban residents to settle, and the housing-price-to-income ratio is the ratio of housing prices to annual household income. It reflects not only the level of urban economic development but also the cost of living of urban residents. With rapid urbanization, housing prices are also rising, especially in first- and second-tier cities that have higher levels of urban development and increasing housing prices. As a result, the impact of real estate on urban human settlements is also increasing. The decisive power of the house price-to-income ratio factor increased from 0.228 in 2000 to 0.433 in 2019, reaching its peak in 2010. In 2010, the state began to implement strong controls on the real estate market, which reduced the differences in the development between cities to a certain extent and weakened its decisive power. An excessively low housing-price-to-income ratio is not conducive to economic transformation and upgradation. An excessively high housing-price-to-income ratio will hinder the healthy development of the economy; it will also cause residents to bear huge pressure to purchase houses and reduce the quality of life of residents. Therefore, the house-price-to-income ratio factor has become a core factor affecting the sustainable development of urban human settlements.

3. Investment in education and scientific research

Education is the endogenous driving force for national progress, and science and technology are the primary productive forces. Thus, promoting science and education can improve the life quality of people. The more high-quality talents, the stronger the promotion of the civilization of the urban population, thus, the stronger the driving force for the development of urban human settlements, and the stronger the national scientific and technological strength. At present, urban residents' pursuit of human settlements has gradually shifted from the material level to cultural improvement. High-quality sustainable development of urban human settlements is impossible without science and technology, which facilitate scientific research, technological capabilities, and increase innovation levels. In recent years, the Chinese government has continuously increased its support for education and scientific research. Public education and research and development expenditures accounted for a major proportion of the GDP; these have also become an important criterion for measuring the level of sustainable development of urban human settlements. Therefore, the government's investment in science and education has accelerated the spatial differentiation of the sustainable development level of urban human settlements, thus increasing their decisive power.

4. Internet penetration rate

The Internet penetration rate refers to the proportion of the total population that uses the Internet. Modern communication infrastructure, represented by the Internet penetration rate, reflects the degree of development of the city. Prefecture-level cities with a higher level of modernization have a strong economic foundation and complete supporting facilities, and the quality of urban human settlements is relatively high. In 2000, China's network development was low. During 2005–2015, the Internet developed rapidly, and the coverage and development speed of the Internet were different because of the different degrees of development of cities. Therefore, the Internet penetration rate greatly affects the sustainable development patterns of urban human settlements. As of December 2019, China's Internet penetration rate reached 67%. In recent years, the steady development of the Internet has narrowed the digital divide between cities. In particular, during the COVID-19 period, the Internet industry has been extremely dynamic and resilient. Services, such as online education, online medical care, remote office, and online shopping have become a solid force for China to respond to new challenges and build a digital economy.

5. $PM_{2.5}$ concentration

$PM_{2.5}$ concentration is an important indicator of the degree of air pollution. The higher the concentration, the greater the threat to the urban natural ecological environment. It is also a key factor in global non-communicable diseases. At the same time, it will indirectly increase the pressure on medical resources and hinder social and economic development. For the sustainable development of urban human settlements, health must be a priority. Improving the health of urban residents is the basis for the development of people's livelihood, and the improvement of people's livelihood is the foundation for the sustainable development of urban human settlements. Due to different urban climate conditions, different degrees of industrialization, and uneven anti-pollution capabilities, the degree of urban air pollution is also different. Therefore, the $PM_{2.5}$ factor is an important negative driving force for the spatial distribution of the sustainable development of urban human settlements. In the past 10 years, China has attached great importance to the prevention and control of air pollution and has formed a strict scientific monitoring system; additionally, environmental protection awareness in urban residents has gradually increased, and urban air quality has been comprehensively and effectively improved. As a result, the determining power of the $PM_{2.5}$ factor was significantly weakened.

5. Discussion

Overall, the sustainable development of urban human settlements in China shows a continuous improvement trend; in particular, the growth rate of development from 2005 to 2010 is obvious. The improvement shows an east to west trend, presenting a spatial pattern of a "high in the east and low in the west; high in the south and low in the north" trend, which is consistent with the research results of Xu (2020) and Meng (2019) [47,48]. In addition, the sustainable development of urban human settlements has significant spatial correlation characteristics. Cities with a high level of sustainable development of urban human settlements are concentrated in the coastal areas of the southeast and the Beijing–Tianjin–Hebei urban agglomeration in North China. Among them, the sustainable development level of urban human settlements in Shenzhen, Hangzhou, Changsha, Guangzhou, and Shanghai has always been at the forefront. To a certain extent, this distribution law is consistent with the findings of Guo (2020) [49]. Urban human settlements in these cities are developing in a comprehensive, balanced, and stable manner, and the overall strength is relatively good. Prefecture-level cities with low levels of sustainable development are concentrated in northeastern and inland cities in the northern region. Similar to the research results of Jia (2017) [50], the development of human settlements in Yichun, Hegang, Qitaihe, and Jixi (among other cities) has always been in a backward position, related to the slow economic development of cities, prominent ecological problems, and serious population loss.

The level of development of the natural system of urban human settlements in China has continued to improve. Consistent with the results of Luo (2020) [51], the natural environment of southern cities in China is better than that of northern cities, and the development level of natural systems in coastal cities is generally higher than that in inland cities. The natural system scores of Shenzhen, Shanghai, Sanya, Hangzhou, and Xiamen were among the best. These cities have strong advantages in terms of air quality, greening level, and resource conservation and utilization. Our study revealed that among the natural environmental factors, $PM_{2.5}$ has a great impact on the sustainable development of urban human settlements. Zhang (2020) proposed that air pollution affects the harmonious relationship between humans and land [52]. Saleem (2019) predicted that $PM_{2.5}$ will affect human health, by indirectly increasing the pressure on medical resources and hindering social and economic development [53]. Therefore, prioritizing the development of the ecological environment is crucial for our sustenance. Especially in cities with fragile ecological environments and low environmental awareness, such as Yichun, Heihe, Baishan, and Tianshui, it is necessary to improve ventilation and resource utilization efficiency [54], encourage the application of green environmental protection technologies, promote the use of clean energy, and encourage urban residents to cultivate the values of green life.

The development of the humanity system in urban human settlements in China has improved significantly, and the overall spatial pattern of "multi-level core-periphery" radial growth is indicated prominently, which to a certain extent, is consistent with the research conclusions of Liu (2019) [55]; notably, Beijing, Hangzhou, Guangzhou, Changsha, and Wuhan were ranked high with respect to development in this system. Our study revealed that unbalanced investment in education and scientific research is the main humanity environmental factor that accelerates the spatial differentiation of the sustainable development of urban human settlements, which is in agreement with the findings of Liu (2019) and Li (2019). More studies have stated that high education levels and innovative capabilities can promote high-quality urban development [55,56]. At the same time, Liu (2019) and Cao (2020) found that China's urban innovation capacity is declining from the coastal to inland areas, which coincides with the results of this study [55,57]. Therefore, it is necessary to continue and increase investment in public education and scientific research, especially in cities such as Jixi, Jinchang, Tongchuan, and Baishan, where education resources are scarce and emigration is high. At the same time, it is necessary to improve talent treatment mechanisms, maximize the stability of local talent, absorb outstanding foreign talent, and promote the improvement of local residents' cultural literacy.

The overall development of the residential system of urban human settlements presents a spatial pattern of expansion and growth from east to west, and the overall development gradually develops from a low-medium level to a medium-high level. Our study revealed that the housing-price-to-income ratio in the housing system is the main factor affecting the sustainable development of urban human settlements. This conclusion is consistent with that of Koetter (2021), Chen (2021), and Yin (2019), who believed that housing is one of the most important needs of urban residents [58], and the housing-price-to-income ratio will affect the process of urbanization [59] and the realization of urban spatial justice [60], which is of great significance to the sustainable development of urban human settlements. Therefore, it is necessary to conduct quantitative, dynamic, and refined analyses with respect to the housing-price-to-income ratio, new houses, and stock houses, and adhere to city-specific policies, especially in cities that have a low level of development in residential systems, such as Hegang, Heihe, Qitaihe, Longnan, and Zhongwei. Furthermore, it is necessary to improve the affordable rental housing system and income distribution mechanism and increase the supervision of land transactions and real estate sales.

The development of the social system of urban human settlements is slowly increasing, and the overall distribution is characterized by the "high in the east and low in the west" trend. Our study revealed that in 2000, cities with a high level of social system development were mainly concentrated in the Heilongjiang, Liaoning, Jiangsu, and Fujian provinces. After 2005, northeastern China was affected by the concept of a planned economic system, and the economic development continued to lag behind, which is consistent with the research of Han (2019) [61]. At the same time, consistent with Zhou (2019) [62], the social system development levels of Beijing, Shenzhen, Guangzhou, Shanghai, Suzhou, and Hangzhou were at the forefront. Barkhatov (2021) and Chen (2021) found that the quality of urban life interacts with the level of economic development, and the stability of economic development greatly affects the level of sustainable development in the region; they also observed that the GDP per capita was an important indicator for measuring the level of economic development [63,64]. This point of view is consistent with the results of our study, which also revealed that there is a strong correlation between the per capita GDP and the spatial pattern of the sustainable development level of urban human settlements. Therefore, in view of the problems of poor and weak industries and irrational industrial structures in the northeastern and western regions, it is necessary to effectively change the idea of development [65] and use big data to simulate and predict the development mode of urban industrial structure, promote the optimization and upgrading of the industrial structure and diversified development, establish a modern corporate governance model, and adhere to the development of a circular and low-carbon economy to achieve a "win-win" situation of social economic development and ecological environment protection.

The development of a support system for urban human settlements has shown a significant upward trend and an overall spatial pattern of unbalanced growth. High-value areas are scattered in the Beijing–Tianjin–Hebei urban agglomeration, East China, and Central and South China. To some extent, this result is consistent with the findings of Du (2020) [66]. Among the many elements of the support system, the Internet penetration rate greatly affects the sustainable development pattern of urban human settlements, which is consistent with the results of Cioaca (2020) and Asongu (2019), who proposed that the high penetration rate and high-quality development of the Internet can strengthen the development of digital technology, which can, in turn, transform into economic and social benefits [67,68]. This can improve the sustainable development of urban human settlements. Therefore, cities with poor communication infrastructure, such as Guigang, Hezhou, Suining, and Longnan, should pay attention to the construction of modern infrastructure service facilities, increase the Internet penetration rate, and improve the level of information communication, while strengthening the construction of intelligent transportation systems, medical systems, and education systems, and accelerate the construction of new smart cities.

6. Conclusions

Over the past 20 years, the overall level of sustainable development of urban human settlements in China has steadily improved. Notably, the development of cities in the southeast was significantly higher than that in the northwest. The main development model considers the transformation from a medium-low development level to a medium-high development level. The per capita GDP, housing-price-to-income ratio, investment in education and scientific research, Internet penetration, and $PM_{2.5}$ concentration have a great impact on the spatial differentiation of the sustainable development of urban human settlements. To achieve the SDGs quickly and effectively, our study proposes high-quality green development orientation to improve the balance and coordination of the development of subsystems of urban human settlements. The research scale of this study is macroscopic, and the time span is large. To ensure the accuracy of the results, it is necessary to fully consider the availability and continuity of the data, so that some indicators cannot be adopted. At the same time, there is a lack of understanding of the psychological needs and behavioral characteristics of urban residents. Therefore, future studies should combine questionnaires, interview data, and more time-sensitive and accurate geographic information data.

Author Contributions: Methodology, software, and data curation, X.C.; formal analysis and writing—original draft preparation, X.C.; writing—review and editing, all authors; funding acquisition, X.L. and Y.G.; supervision, all authors. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Ministry of Education Humanities and Social Sciences Research Program (Grant no. 18YJCZH035), the Liaoning Education Department Scientific Research

Project (Grant no. J2020060), and the Dalian Science and Technology Innovation Fund Project (Grant no. 2020JJ26GX039).

Data Availability Statement: The data presented in this study are available upon request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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