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Article

Traditional Village Morphological Characteristics and Driving Mechanism from a Rural Sustainability Perspective: Evidence from Jiangsu Province

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Abstract: (1) Background: The sustainable development of rural areas has become a critical factor in global economic and social transformation. As an essential part of China's rural ecological and cultural system, traditional villages are now facing a crisis of yearly decline, and sustainable development has become a meaningful way to solve the problem. This study utilized morphological indicator analysis and the SDGs as an evaluation framework to reveal the correlation and driving factors between traditional villages' spatial form and sustainability indicators. From the perspective of the spatial form, this approach has specific reference significance for improving the sustainability of traditional villages. (2) Methods: A framework for detecting the driving factors of rural sustainability based on four dimensions (morphology, environment, economy, and society) was constructed. A geographic information system (GIS) was used to analyze the geographic patterns and morphological indicator characteristics of traditional villages in Jiangsu Province, and GeoDetector was used to analyze the driving mechanisms of the spatial patterns of sustainability in traditional villages, providing the basis for spatial zoning and differentiated policy design for the construction, planning, and management of sustainable villages. (3) Results: ① The spatial patterns and morphological characteristics of traditional villages exhibit prominent geographical imbalances and significant cluster cores. ② The high-density and low-aspect-ratio rural form in the southern region (where rural industries are developed) promotes good economic sustainability in rural areas but also leads to poor environmental performance. The rural areas in the southwest and north (high-density forest areas) have medium density and a high aspect ratio, and the lack of agricultural space and external connections affects their social performance. The main focus is on poverty reduction and urban cooperation. The central and northern lakeside areas and the eastern coastal areas (important ecological protection areas) have low density and high aspect ratios, which have helped them to achieve excellent environmental performance but also led to contradictions in environmental, economic, and social performance. Maintaining low-density patterns, using clean energy, and protecting terrestrial and underwater biodiversity are essential to the sustainability of the rural environment. The agglomeration of spatial patterns promotes cooperation between rural and urban areas and improves industrial development, contributing to the sustainability of the rural economy. Improving social welfare and agricultural development contributes to the sustainability of rural societies. ③ The impacts of various factors vary significantly; for example, Life below Water (SDG14), Climate Action (SDG13), and No Poverty (SDG1) are the most prominent, followed by Partnerships for the Goals (SDG17), Affordable and Clean Energy (SDG7), and Recent Work and Economic Growth (SDG8). (4) Conclusions: It is recommended that the government, with the driving mechanisms, divide the spatial management zoning of traditional villages in Jiangsu into three types of policy areas: environmental-oriented, economic-oriented, and social-oriented. Differentiated and targeted suggestions should be proposed to provide a critical decision-making basis for protecting and utilizing traditional villages in Jiangsu and similar provinces, as well as to help promote rural revitalization and sustainable rural construction in China.

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Keywords: rural sustainability; traditional village; morphological characteristics; driving mechanism

1. Introduction

1.1. Background

Since the United Nations put forward "Transforming our World: The 2030 Agenda for Sustainable Development" in 2015, this has signaled that global governance and both urban and rural sustainable development have become new global trends. For a long time, urban sustainable development has continued to receive attention from the international community. Still, the significance of the sustainable development of rural areas, as an essential part of human society, has been neglected. This has become a bottleneck in the global realization of the United Nations' framework system of Sustainable Development Goals (SDGs). In recent years, rural sustainability assessment has played an increasingly important role in the economic and social development, infrastructure construction, and cultural and ecological protection of traditional villages and rural areas in developed countries such as the United States, members of the European Union, Australia, and Canada, all of which have formulated strategies for sustainable rural development in response to urban–rural disparities, cultural segregation, population aging, inequality, etc. The United Nations Economic and Social Council published a report concerning rural sustainable development, and the Bertelsmann Foundation dynamically published "The Sustainable Development Goals Report 2022". While rural areas in Africa and developing countries are particularly susceptible to severe land degradation, widespread poverty, food insecurity, and malnutrition, a concerted effort exists to promote low-cost and efficient agricultural models and the digital preservation of rural cultural heritage.

As the largest developing country, China has always considered rural revitalization to be a crucial strategy for promoting sustainable rural development in the new era. Establishing a set of indicators for assessing the sustainable development of rural areas and guiding the creation of sustainable spatial patterns in these areas has become an essential aspect in formulating programs for the sustainable development of the countryside. For the vast rural areas, the Central Committee of the Communist Party of China and the State Council have successively issued the "Guiding Opinions on Improving the Rural Habitat Environment", "Rural Revitalization, Comprehensively Promoting Rural Revitalization and Implementing the Digital Rural Construction and Development Project", and "the Three-Year Action Program for Rural Habitat Improvement and other policy documents", providing policy guarantees for the sustainable development of the countryside and offering continuous solutions to the challenging problems in the transformation process of sustainable development. It is worth noting that the rural spatial form, as an external characterization of the transformation of and change in rural sustainability factors, is also a key area of concern for relevant policies. Therefore, this paper focuses on the quantitative analysis of the development levels, morphological correlations, and factors influencing the sustainability of the countryside, significantly improving the theoretical system and promoting better practice.

1.2. Literature Review

1.2.1. Research on the Interaction between Rural Sustainability and Morphology

At present, research on the spatial form of villages mainly focuses on typological analyses [1,2], cultural anthropology [3], ethnology [4], folklore [5], rural settlement geography [6,7], and vernacular architecture [8,9]. In contrast, research on rural sustainability mainly focuses on the relevant elements, indicator systems, and governance methods of sustainable development. Since the 19th century, scholars such as Kohl, Meitzen, Blache, and Christaler have researched settlement patterns, focusing on qualitatively describing the original form, location conditions, and distribution patterns. Hiroshi Hara and Fujii Akira studied the morphology of rural settlements from the perspectives of typology and ethnology, summarizing the spatial location, overall structure, and typological differences of settlement clusters, and focusing on the impacts of terrain differences, social and demographic changes, and other driving factors on village location [10]. Demandion [11], Dickinson, and Christeller have selected indicators such as shape, regularity, and openness to classify and calculate villages' spatial morphology [12]. However, due to differences in calculation methods, spatial scales, and data caliber, the calculation results of traditional villages' spatial morphology vary significantly, lacking more reliable and accurate conclusions.

Under the trend of global sustainable development, as qualitative research on rural settlement models gradually matures in theory and practice, people are paying increasing attention to the coupling of research between village spatial patterns and village sustainability. How can the rural living model adapt to sustainability requirements and help in achieving the Sustainable Development Goals? What is the mechanism linking rural spatial patterns with rural sustainable development? These are urgent questions that need to be answered.

Firstly, from a theoretical and academic perspective, as sustainable villages change and spatial patterns are built, scholars are still uncertain about the factors that influence their research's formation, evolution, and driving mechanisms. This has led to a lack of essential components for constructing a theoretical framework. In other words, what factors lead to the significant differences in the sustainability of the countryside and its spatial morphology changes in different regions, and what are the relationships between these factors? A rational spatial pattern of the countryside can improve the resource utilization efficiency. For example, rational rural planning can lead to a greater concentration of buildings, industries, and infrastructure with different functions, reducing transportation energy consumption, industrial pollution, and land occupation. Secondly, a low-density, strong, recognizable rural spatial form can protect the ecological environment and local culture while enhancing the visual experience of tourists and rural tourism. For example, studies on famous tourist villages, including 57 tourist villages in Fujian Province [13], Longchuan Village in Anhui Province [14], and Luxiang Village and Mingyuewan Village in Jiangsu Province [15], have found that the sustainable development of villages, especially traditional villages, cannot be separated from the protection of their original and iconic spatial form. It is essential to summarize the regional laws regarding the characteristics of the rural spatial form. At the same time, the cluster protection of traditional villages' spatial forms is also of leading significance for the sustainable development of villages in watersheds. Relevant scholars, in their studies of traditional villages in watersheds such as the Yellow River Basin [16], the Qiantang River Basin [17], and the Qinhe River [18], have proposed territorial governance strategies in response to the significant differences in the distribution patterns of village systems at different spatial scales. However, they have failed to address the issue of influencing factors and their mechanisms of action.

Secondly, in terms of practical application needs, the sustainability of the countryside and its morphological characteristics vary significantly from country to country and from region to region. The government urgently needs to assess the scientific correlation between sustainable development and the morphological characteristics of the countryside, in order to provide a basis for designing management policies and construction planning. In addition to China, governments in many other countries and regions are committed to promoting sustainable rural development. Wu [19] revealed the spatiotemporal imbalances of traditional Chinese villages from the perspectives of spatiotemporal characteristics and scale effects, proposing a differentiated protection model for traditional Chinese villages. Liu [20] used a decision tree model, spatial lag regression model, and geographic detector to analyze the spatial distribution patterns and influencing factors of traditional villages in Henan Province. Zhu [21] took traditional villages in Zhejiang Province as a case study to reveal the formation and evolution of external morphological characteristics and the internal spatial structure. Liu [22] proposed a spatial pattern analysis framework based on pattern language theory using KED, NNI SSIA, and other methods. Liu [23] used participant observations and interviews to analyze the impacts of photovoltaic systems on the social–spatial structure, rural governance models, and rural sustainability. However, these practices are more empirical and exploratory, without quantitative or scientific evidence. In other words, policymakers lack a systematic set of technical tools to provide a basis for decision making with regard to the requirements of sustainable rural development.

The Sustainable Development Goals (SDGs) proposed by the United Nations provided specific guidance for this study (Figure 1). The 2030 Agenda includes 17 Sustainable Development Goals (SDGs) and 169 specific sub-goals, which can be mainly divided into economic, social, and environmental systems. This article is based on the perspective of the correlation between the rural spatial form and sustainable development. Studies have analyzed the interactive relationship between the rural spatial form and sustainable development from the viewpoints of form, economy, society, and environment. Yin [24], based on the 17 Sustainable Development Goals (SDGs), constructed an economic–social–environmental (ESE) quantitative analysis system, revealing the sustainable characteristics of the urban spatial structure in the Yangtze River Delta urban agglomeration. Opon and Henry [25] used causal network analysis to design an overall indicator framework for evaluating the sustainability of concrete materials. This framework decomposes the Sustainable Development Goals (SDGs) into three dimensions: environmental stewardship, economic growth, and social wellbeing. These studies have laid a solid foundation for forming the indicator framework proposed in this article.

Figure 1. United Nations Sustainable Development Goals (SDGs) (Available online: https://www.un.org/sustainabledevelopment/sustainable-development-goals/, accessed on 3 March 2021.)

1.2.2. Analysis of Village Morphology Indicators

The analysis of villages' spatial morphology is widely used in the quantitative descriptions of settlement morphology, which is used to express the spatial morphological characteristics of traditional villages. In recent years, the use of morphological indicator models to study the spatial morphology of traditional villages has emerged as a new research field. The application of new technologies and methods is increasing, including Space Syntax [26,27], machine learning [28,29], BIM technology [30,31], SD (system dynamics) technology [32,33], and CA (cellular automaton) technology [34,35]. These methods are applied in the fields of static and dynamic quantitative calculations for analyzing the spatial morphology of traditional villages [36], as well as their driving factors [37,38], and for simulating planning scenarios [39]. Representative results include the following. Pu [40] used the concept of fractal dimensions for the calculation and preliminary analysis of public spaces in traditional residential houses. Li [41] established a method to capture rural community residents' landscape values and preferences by combining participatory mapping with questionnaire interviews. Liu [42] took traditional villages in the west of Beijing as study objects and, based on the box-counting dimension method of fractal theory, calculated the different types of spatial values in the external space of the villages. Huang [43] used the Space Syntax and Space Resistance Model to conduct experimental research on optimization strategies for the commercial layouts of traditional villages such as Longchuan Village in Anhui Province.

In general, there is a growing trend of research on quantitative indicator models for traditional village morphology. Still, there are two general characteristics. First, macro-scale research focuses on areas such as the geographical distribution of village sites and their driving mechanisms. Second, micro-scale research focuses on the analysis of morphological indicators, with the core consisting of exploring methods such as the rapid quantification of village morphology using the aspect ratio and building density indicators. Therefore, it is of great theoretical significance and practical value to carry out large-sample quantitative research on the spatial morphology of traditional villages using the aspect ratio, building density indicators, and spectral clustering analysis methods to provide a basis for decision making on the protection and use of traditional village clusters and their sustainable development.

1.3. Research Gaps and Issues

There are three deficiencies in the current research. Firstly, there has been a greater focus on studies concerning village sustainability independent of spatial form, with fewer studies integrating these two aspects. The existing studies have predominantly concentrated on individual village case studies and lack comprehensive regional analyses. Secondly, research on village sustainability has concentrated primarily on associated elements, indicator systems, and governance methods, with little attention paid to the impact of village form on village sustainability and residents' wellbeing. Thirdly, traditional villages are essentially the product of the integrated formation of regional nature, culture, economy, and society. However, the current literature lacks spatial correlation analyses from a regional perspective, and exploring driving mechanisms often overlooks the influence of spatial and interactive effects.

To address the aforementioned deficiencies, this paper presents a spatial measurement modeling approach that utilizes a combination of morphology index calculations, ArcGIS 10.2 analysis, and GeoDetector_2015 to examine the spatial pattern laws in Jiangsu Province. Furthermore, this approach aims to uncover the driving mechanisms behind these patterns and subsequently propose targeted recommendations and planning strategies based on performance assessments. This study's research objectives were as follows. (1) Use ArcGIS to quantitatively measure the spatial characteristics of the spatial patterns of traditional villages in Jiangsu and to reveal their spatial effects in the spatial dimension. (2) Assess its performance based on the indicators of sustainable development of the countryside and analyze the correlation between the spatial morphology of the traditional villages and the indicators of sustainable development of the countryside. (3) Measure the direct impacts of various factors on the spatial distribution patterns and identify the spatial and interactive influencing factors using GeoDetector. (4) Propose targeted management policies and planning design suggestions based on the analysis results. These suggestions will serve as a foundation for the government to scientifically formulate and dynamically adjust policies regarding the conservation and utilization of traditional villages, ultimately enhancing the effectiveness and practicality of relevant policies.

2. Materials and Methods

2.1. Study Area: Jiangsu Province, China

(1) The Reason for Choosing Jiangsu

The study area was Jiangsu Province, China, including 13 cities and 95 counties (Figure 2). We chose Jiangsu mainly due to its stage of economic development and rural construction practices.

Figure 2. Study area.

Firstly, Jiangsu is a highly urbanized coastal economic province, and the urbanization rate of the resident population in Jiangsu Province has reached 74.42%, placing it among the top three in China. As a representative highly urbanized region of the Yangtze River Delta and China, Jiangsu is experiencing a more intense rate and magnitude of urban expansion. Thus, its unique livelihood industry, agricultural landscape, demographic composition, and regional characteristics of traditional villages are under serious threat. Still, the industrial and economic capital accumulated through rapid urbanization can support the region's pioneering efforts in green transformation. This research sample in Jiangsu will be of great value for solving the problems of sustainable rural development, promoting the sustainable use of ecological resources, civilization inheritance, talent and creativity cultivation, and the continuation of national memory in rural areas [43].

Secondly, Jiangsu attaches great importance to the construction of sustainable countryside and has achieved stage-by-stage results but faces problems such as the lack of guidance for constructing rural spatial patterns. Promoted by the national pilot and supported by the central government, Jiangsu has carried out the pilot construction of beautiful provincial-level villages, characteristic idyllic villages, traditional villages, and harmonious villages in 13 cities, 95 counties, and 10,000 villages. In the Jiangsu Initiative on Green Urban and Rural Construction under the "Dual Carbon" goal, the provincial government put forward the development goal of "comprehensively promoting green urban and rural construction and building sustainable human settlements". Municipal and county governments also attach great importance to sustainable rural construction. For example, Suzhou, the national model city for the protection and use of traditional villages, has issued the "Guiding Opinions on Effectively Strengthening the Protection, Use, and Development of Traditional Villages in the City", which further strengthens the protection of villages, rationally utilizes the value of village resources, promotes the sustainable development of villages with the protection of spatial forms, and strives to realize the living inheritance and promote the revitalization of rural development; Suzhou has been selected as an excellent national case. However, there are still problems, such as regional imbalances in the sustainable development of villages and the urbanization of rural spatial pattern construction methods in Jiangsu.

Generally speaking, as a critical experimental area of "Beautiful China" and the "Two Mountains" theory, Jiangsu is the first region to pay attention to the transformation of rural sustainability, which is typical and representative of China. Taking traditional villages in Jiangsu as the research objects is of great theoretical value and practical significance for analyzing the relationships between the spatial characteristics of traditional villages and rural sustainability, as well as for providing a decision-making basis for the protection, utilization, and sustainable development of traditional villages in the region.

(2) Principles for Selecting Case Villages

To ensure that the selected samples fully reflect the multidimensional characteristics of traditional villages in Jiangsu Province, we formulated the following two principles for selecting the case villages. Firstly, emphasis should be placed on the principle of regional balance. The sample size was determined based on the scope and complexity of natural or administrative divisions to maximize a balanced distribution, and the number of cases in each city could be no less than 2. Secondly, considering the differences in the environment, economy, social conditions, and settlement morphology of traditional villages, 80 rural settlements were selected from 439 traditional villages as research samples for quantifying the morphology index (Figure 3). Subsequently, each research sample was classified according to four primary attributes: environment, economy, society, and settlement morphology.

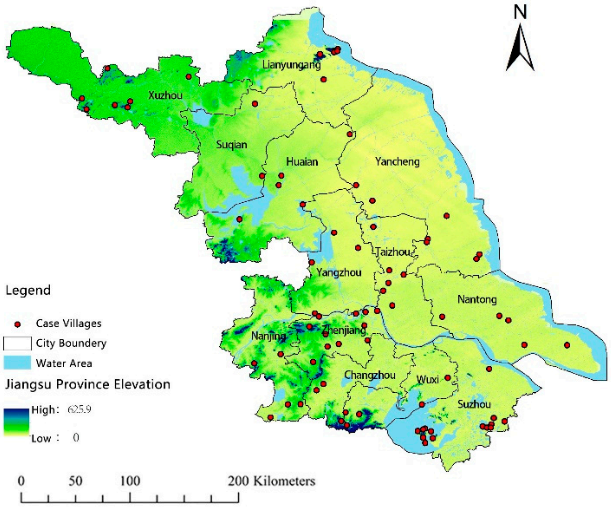

Figure 3. Case study villages.

2.2. Research Steps and Technical Roadmap

This study was based on multiple measurement models, with five steps (Figure 4).

The first step was the collection and processing of raw data. The architectural plan data and the environmental, economic, and social data of traditional villages in the study area were sorted out and entered into the ArcGIS platform.

In the second step, ArcGIS was used to calculate the scores of the 17 SDG indicators in different regions. Then, using the form data of 80 traditional village cases, the aspect ratio and building density indicators were calculated to form an index distribution map.

The third step, combined with ArcGIS spatial analysis, was to analyze the spatial distribution and morphological index heterogeneity of the traditional villages. Next, spatial differences in rural sustainability were analyzed from the "environmental–economic–social" perspective, and Getis–Ord Gi* (ArcGIS 10.2) was used to assess the spatial distribution of the 17 SDGs for rural sustainable development.

In the fourth step, using GeoDetector_2015, the driving mechanisms of spatial patterns were quantitatively analyzed, including factor importance, spatial effects, and interaction effects. The driving mechanisms of the spatial patterns of traditional villages were examined from the perspective of sustainable rural development.

In the fifth step, based on the results of the analyses in the above steps, planning and management recommendations were put forward as a guide and basis for the design of policies for the sustainable development of the countryside, and for the conservation and utilization of the spatial patterns in traditional villages.

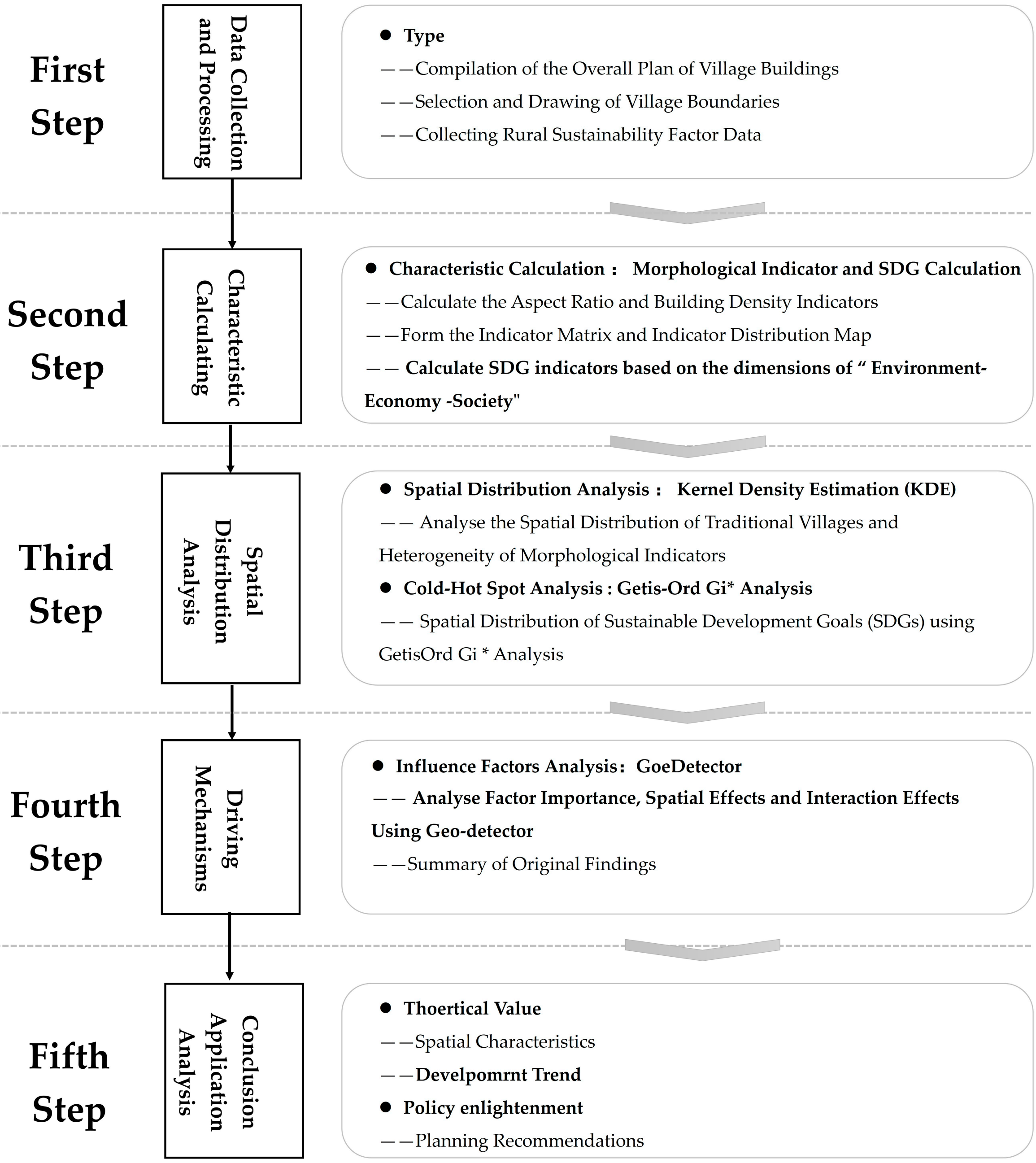

Figure 4. Research steps.

2.3. Research Methods: Morphological Indicator Calculation Model

Based on quantitative research method, we used the UTM (Universal Transverse Mercator) coordinate system to draw the two-dimensional (2D) plane shape and boundaries of traditional village samples using the AutoCAD 2016 platform. Mathematical analyses were conducted on several characteristics, such as the building density (M) and aspect ratio (λ), and the numerical results were input into the ArcGIS platform. Then, bar graph tools were used to display the spatial form indicators of traditional villages in Jiangsu, providing a basis for distinguishing the spatial form types of traditional villages in the future.

2.3.1. Morphological Quantitative Calculation

In this study, the shape index calculation method was adopted, which selects the aspect ratio (λ) and building density (M) to calculate the shape index of individual village cases (Figure 5). We comprehensively analyzed the spatial form indicators of traditional villages in 80 cases based on different city classifications, and we explored the possible non-equilibrium characteristics between cities within the province.

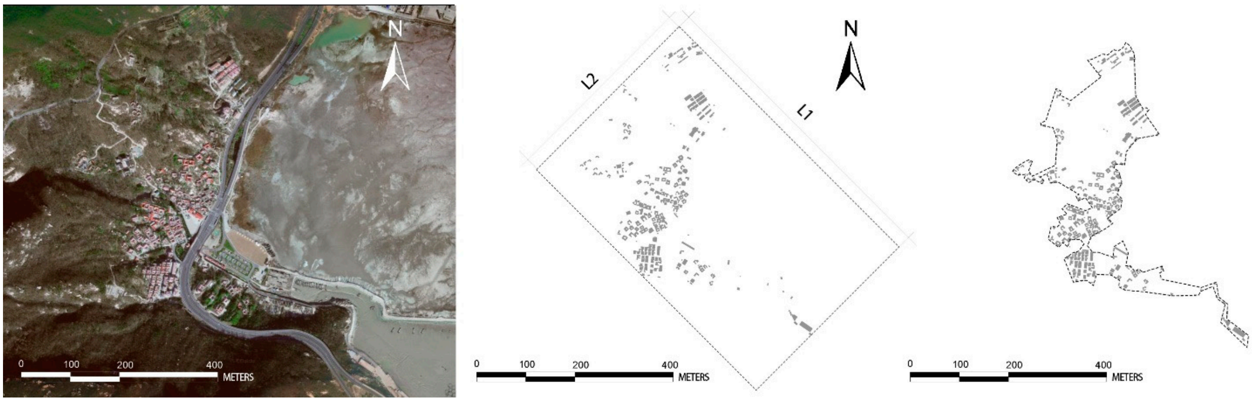

Figure 5. Calculation methods for aspect ratio (λ) and density (M).

(1) Aspect Ratio (λ)

The aspect ratio is the ratio of the long axis ($L1$) to the short axis ($L2$) of the settlement boundary graph, and it is also the zonal index of the settlement; it is usually determined using the aspect ratio of its outer rectangle. The formula is as follows:

$$\lambda = \frac{L1}{L2} \tag{1}$$

(2) Building Density (M)

Among the architectural terms that quantitatively describe a settlement space, the most classic is the building density index. This is the ratio of the base area of the village's buildings to the graphical area of the settlement boundary, which directly reflects the building density of settlement buildings in the village. The calculation formula is as follows, where M is the settlement building density, S' is the total area of the village building base, and A' is the area of the settlement boundary graph:

$$M = \frac{S'}{A'} \tag{2}$$

2.3.2. ArcGIS Spatial Analysis

(1) Kernel Density Estimation (KDE)

The kernel density estimation (KDE) visually represents the density distribution of a village and is utilized to identify scattered and concentrated areas within the village area. This reveals the changes in the village's spatial density and can reveal regional differences in the overall pattern of the village's evolution. Here, we employed KDE to specifically focus on expressing the spatial agglomeration characteristics of traditional villages in Jiangsu, based on which we extracted the spatial agglomeration pattern of rural settlements. The predicted density for a new location (x, y) is determined as follows:

$$Density = \frac{1}{(radius)^2} \sum_{i=1}^{n} \left[\frac{3}{\pi} pop_i \left(1 - \left(\frac{dist_i}{radius} \right)^2 \right)^2 \right] \tag{3}$$

$$\text{or} dist_i < radius$$

where $i = 1, \ldots, n$ represents the input points. Points are only included in the sum if they are located within a certain radius of location (x, y).

Pop_i is the population field value of point I, and it is an optional parameter.

$Dist_i$ is the distance between point i and location (x, y).

Then, the calculated density should be multiplied by the number of points or the sum of the population field (if applicable). This correction adjusts the space quota to equal the number of points (or the sum of the population field) instead of being equal to 1. A separate formula must be calculated for each location where the density is to be estimated. As a raster is being created, the calculation will be implemented at the center of each element in the output raster.

(2) Nearest Neighbor Index (NNI)

Traditional villages have three types of spatial distribution: random, uniform, and agglomerative. In this study, we used the NNI method to determine the spatial agglomeration type of traditional villages in Jiangsu Province. The NNI uses the distribution of random patterns as a standard to measure the spatial distribution of point elements [41]. We calculated the nearest neighbor distance of each point feature in the study area and took the average value, i.e., the nearest neighbor distance of point features, denoted by d. The average value of the nearest neighbor distance in the random pattern of point elements is the theoretical nearest neighbor distance, represented by d_{min}. In complete spatial randomness (CSR), the average NNI can also be obtained, and its expectation is $\sum d_{min}$, represented by the following formula:

$$d_{min} = \frac{1}{n}\sum_{1=1}^{n} d_{min} \tag{4}$$

In terms of this study, the average NNI in the random mode was related to the area A and the number of events n, considering the boundary correction of the study area. The following formula represents this:

$$\sum d_{min} = \frac{1}{2}\sqrt{\frac{A}{N}} + \left(0.051 + \frac{0.041}{\sqrt{n}}\right)\frac{p}{n} \tag{5}$$

(3) Getis–Ord Gi*

The Getis–Ord Gi* is a commonly used method for exploring the spatial autocorrelation of features. This technique can detect hot spots (areas with high clustered values) and cold spots (areas with low clustered values) in a study area [44,45]. It should be noted that a feature with a high value may not necessarily be a statistically significant hot spot. To be considered a statistically significant hot spot, an area must meet two conditions: (1) it has a high feature value and (2) it is spatially surrounded by other areas with high feature values.

In this study, the Getis–Ord G_i^* was used to analyze the spatial autocorrelation characteristics of each SDG at the rural scale, as follows:

$$G_i^* = \frac{\sum_{j=1}^{n} x_j w_{i,j} - \overline{X}\sum_{j=1}^{n} w_{i,j}}{S \times \sqrt{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]/(n-1)}} \tag{6}$$

where G_i^* is the z-score, and higher z-scores (hot spots) indicate better sustainability, while lower z-scores (cold spots) indicate the opposite; x_j is the SDG score of city j; $w_{i,j}$ is the spatial weight between village area i and village area j; X is the mean SDG value; n is the total number of village areas; and S is the standard deviation of the SDG scores for all village areas.

2.3.3. GeoDetector

GeoDetector is widely utilized in the study of natural, economic, and social influencing factors [46,47]. This method quantifies the relative importance of independent variables in relation to dependent variables by analyzing overall variability across various geospatial regions; it also demonstrates significant advantages in addressing mixed data [48]. Given that the focus of this study was on detecting the spatial patterns of traditional village distributions, morphological indicators, and the underlying drivers—particularly those involving mixed data—the GeoDetector method was well suited for this study. GeoDetector encompasses four functional modules: factor detection, interaction detection, risk detection, and ecological detection. The associated algorithms and software can be accessed at http://www.geodetector.cn (accessed on 21 March 2021).

In this study, two functional modules—factor detection and interaction detection—were utilized to investigate the impacts of influencing factors and their interactions on the morphological data of 80 traditional villages in Jiangsu Province and the indicators of sustainable urban and rural development at the county level. The factor detection module was utilized to determine whether the disparity in the geographical distribution of independent variables was responsible for the spatial differentiation of dependent variables. The interaction detection module, on the other hand, primarily aims to ascertain whether the individual variables independently contribute to explaining the dependent variables, or if they interact to either enhance or diminish this explanatory power.

In GeoDetector, the q index is used to quantify the degree to which factor (X_i) accounts for the spatial variation in attribute (Y_i), where q (X_i) represents the direct influence and q ($X_i \cap X_j$) represents the interactive influence. The maximum value of the q index is one, and the minimum is zero. A larger value of the q index indicates a stronger influence of the independent variable on the dependent variable. GeoDetector calculates the q index by analyzing the similarity between the geographical distribution patterns of X_i and Y_i. The software produces a higher q index when there is a greater similarity in the geographical distribution patterns between independent and dependent variables [49]. The calculation for the q index is as follows [50]:

$$q = 1 - \frac{\Sigma_{h=1}^{l} N_h \sigma_h^2}{N\sigma^2} = 1 - \frac{SSW}{SST} \tag{7}$$

$$SSW = \Sigma_{h=1}^{\,l} N_h \sigma_h^2 \tag{8}$$

$$SST = N\sigma^2 \tag{9}$$

where h represents the classification number of the influence factor (X_i). The spatial clustering algorithm is commonly used to compare and analyze geographical distribution patterns, and this data discretization process can enhance the stability and smoothness of the model. For layer h and the study area, Nh and N represent the number of traditional villages, σ_h^2 and σ^2 denote the variance of sustainable rural development levels (Y_i), and SSW and SST represent the sums of squares. The interaction relationship can be classified into five types based on the relationship between the interaction influence and direct influence (Max (q (X_i)), q (X_j)), min (Min (q (X_i), q (X_j)) and sum (q (X_i) + q (X_j)) [51].

2.4. Indicator Selection and Data Sources

Drawing on the SDGs indicator system, we believe that the connotations of rural sustainable development include three dimensions, environment, economy, and society, and the achievement of the Sustainable Development Goals in these three dimensions is closely related to the spatial patterns, affecting the efficiency of rural resource utilization and ecological security. Correspondingly, the state of sustainability in the countryside will have multiple effects on the spatial form of the village, which can not only test the optimization and enhancement effects of the spatial form, but also provide guidance for its direction. Therefore, there is a complex interactive relationship between villages' spatial morphology and rural sustainability. The spatial distribution, morphology, and density of villages affect the state of rural sustainability, while changes in the state of rural sustainability will lead to new adjustments in the morphology, demographic structure, industrial structure, and consumption structure of the rural territorial system, ultimately achieving a dynamic balance whereby these factors promote one another.

In this paper, the spatial morphological characteristics of traditional villages are defined as dependent variables. The larger the spatial distribution pattern's kernel density value, the higher the spatial agglomeration and the better the regional protection status of traditional villages. Larger values of the aspect ratio index and building density index indicate more prominent geographical representation and richness of the morphology. Due to the vigorous promotion of rural revitalization and traditional village conservation by the Chinese government in recent years, these three indicators were taken as dependent variables.

However, due to the lack of specific research on the factors influencing rural sustainability in the spatial patterns of traditional villages, it is not possible to directly draw on the research experience of other scholars. China has not yet released an official program for measuring the levels of rural sustainable development and constructing an indicator system. Shao [52] proposed an indicator system for four types of objectives: production factors, natural factors, social factors, and rural governance; while Mo [53] developed a four-dimensional evaluation system for rural ecological space, including a rural tourism resource system, environmental system, economic system, and management service system. Wang [54] constructed an index system for evaluating the livelihood capital of rural households in rural tourist areas incorporating cultural capital, and the livelihood capital of rural households was quantitatively assessed in six dimensions: natural, physical, financial, human, social, and cultural capital. Therefore, after comprehensively considering the above indicators as research data, the rural sustainability indicator system of this paper is summarized. By analyzing the results related to rural sustainability, we were able to extract a set of possible influencing factors. Firstly, the environmental system factors are the fundamental basis of the countryside; the elevation, forest coverage rate, water system density, fishery revenue/total GDP, natural gas penetration rate, and wastewater treatment rate were selected to characterize the environmental elements. Secondly, economic system factors provide the power for sustainable development in the countryside, so the gross domestic product (GDP), GDP of secondary industry added value, number of fixed telephone users/resident population, facility agriculture area, and government revenue were chosen to characterize them [55]. Thirdly, the social system elements are the foundation of stability in the countryside, so the number of permanent residents, disposable income difference, number of middle school students, number of searches per capita for "gender equality", number of hospital beds per 10,000 people, and number of beds in various social welfare adoption units per 10,000 people were chosen to characterize them. In conclusion, this study constructed an indicator system that analyzes the driving mechanisms from the perspectives of environmental, economic, and social development (Table 1).

Table 1. Interpretation table for variable indicators.

Variable	Code	SDG Type	Indicator	Type
Dependent	Y1	-	Spatial Distribution of Traditional Villages (SD)	Morphology System
	Y2	-	Spatial Pattern Distribution of Building Density Indicators (λ)	
	Y3	-	Spatial Pattern Distribution of Aspect Ratio Indicators (M)	
Independent	X1	SDG15— Life on Land	Elevation (DEM)	Environmental System
	X2	SDG13— Climate Action	Forest Coverage Rate	
	X3	SDG6— Clean Water and Sanitation	Distribution of Water Systems	

Table 1. *Cont.*

Variable	Code	SDG Type	Indicator	Type
Independent	X4	SDG14—Life bellow Water	Fishery Revenue	Environmental System
	X5	SDG7—Affordable and Clean Energy	Penetration Rate of Natural Gas (%)	
	X6	SDG12—Responsible Consumption and Production	Wastewater Treatment Rate (%)	
	X7	SDG8—Decent Work and Economic Growth	Gross Domestic Product (GDP)	Economic System
	X8	SDG9—Industry, Innovation, and Infrastructure	GDP of Secondary Industry Added Value	
	X9	SDG2—Zero Hunger	Facility Agriculture Area	
	X10	SDG17—Partnerships for The Goals	Number of Fixed Telephone Users/Resident Population (%)	
	X11	SDG1—No Poverty	Government Revenue	
	X12	SDG11—Sustainable Cities and Communities	Number of Permanent Residents	Social System
	X13	SDG10—Reduced Inequalities	Disposable Income Difference: Urban/Rural (%)	
	X14	SDG4—Quality Education	Number of Middle School Students in School	
	X15	SDG5—Gender Equality	Number of Searches Per Capita for “Gender Equality”	
	X16	SDG3—Good Health and Well-being	Number of Hospital Beds Per 10,000 People	
	X17	SDG16—Peace, Justice, and Strong Institutions	Number of Beds in Various Social Welfare Adoption Units Per 10,000 People	

3. Results

3.1. Spatial Pattern Analysis

3.1.1. Traditional Village Spatial Pattern (Y1)

Figure 6 visualizes the distribution status of traditional villages in geographic space, summarizing the spatial distribution pattern characteristics of traditional villages in Jiangsu; the overall spatial distribution presents two characteristics. (1) The distribution of traditional villages in Jiangsu presents an obvious phenomenon of mountainous and watery agglomerations, where the traditional villages with the characteristics of water networks account for 32%, while those with the characteristics of hilly areas account for 29%. The largest traditional village clusters are formed near the Ningzhen Mountains, Yili Mountains, and around Taihu Lake. It can be seen that the location and growth of traditional villages cannot be separated from the superior natural ecological factors in the region. (2) Traditional villages in Jiangsu also show the phenomenon of clustering toward cultural routes. The Beijing–Hangzhou Grand Canal, its main branch lines, and the Crosstown River connect a considerable number of traditional villages, and the high number and integration of ancient villages along the line are closely related to the water transport function of the canal, indicating that the social and cultural driving factors influence the spatial patterns of traditional villages.

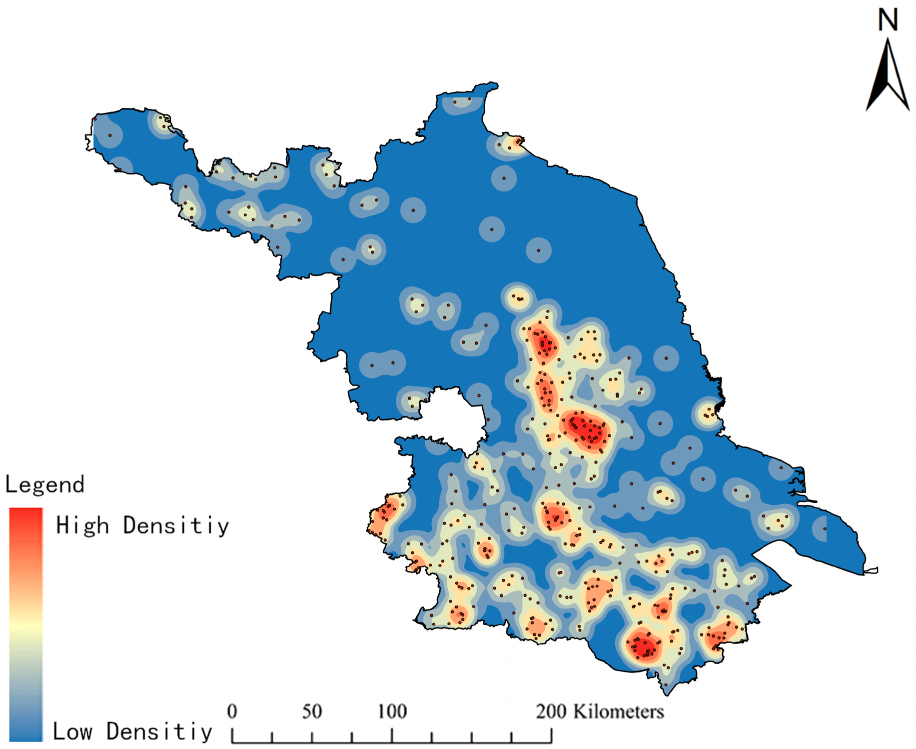

Figure 6. Spatial distribution map of dependent variables (Y1).

3.1.2. Morphological Characteristics of Different Cities

The aspect ratios of traditional villages in Jiangsu Province are generally below 2.0, i.e., finger-like or cluster-like features, accounting for 65% of the total. The traditional villages in Yancheng all have aspect ratios greater than 2.0, and they are all in the coastal reclamation area. Meanwhile, 27.27% of traditional villages in Zhenjiang have aspect ratios greater than 2.0, which are mainly located in polder areas of the Yangtze River (Figure 7, Appendix A—Table A1).

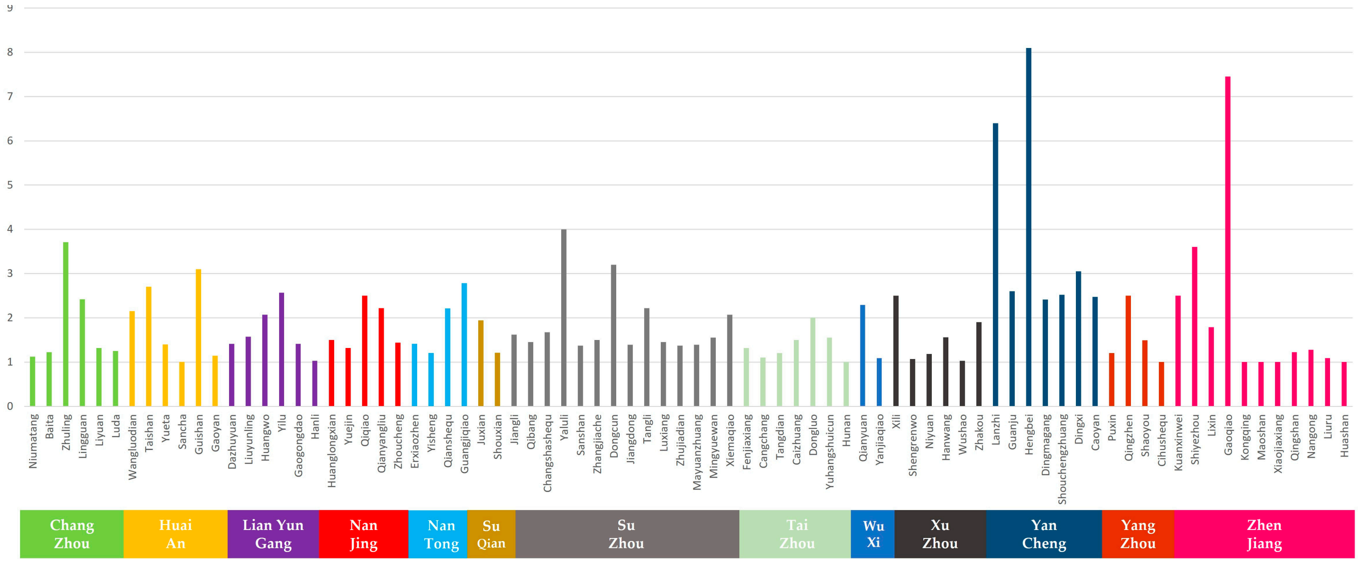

Figure 7. Analysis of the aspect ratios of traditional villages in different cities.

The traditional villages in Jiangsu Province with high building density values are mainly distributed around Taihu Lake, the Ningzhen area, and the Xuzhou Plain area. Among them, the building densities in Nanjing and Wuxi are above 0.25, 87.50% of traditional villages in Suzhou are above 0.20, and 81.82% of traditional villages in Zhenjiang are above 0.20, mainly influenced by the plains and hilly terrain and the developed local economy [56]. The building density of traditional villages in Jiangsu Province is distributed primarily in the coastal area, mainly influenced by the coastal mountainous terrain and the agricultural and industrial structures of the plains' reclamation area. Meanwhile, 66.67% of the traditional villages in Lianyungang have a building density of less than 0.15, 42.86% of the traditional villages in Yancheng have a building density of less than 0.15, and 50.00% of the traditional villages in Nantong have a building density of less than 0.20 (Figure 8, Appendix A—Table A1).

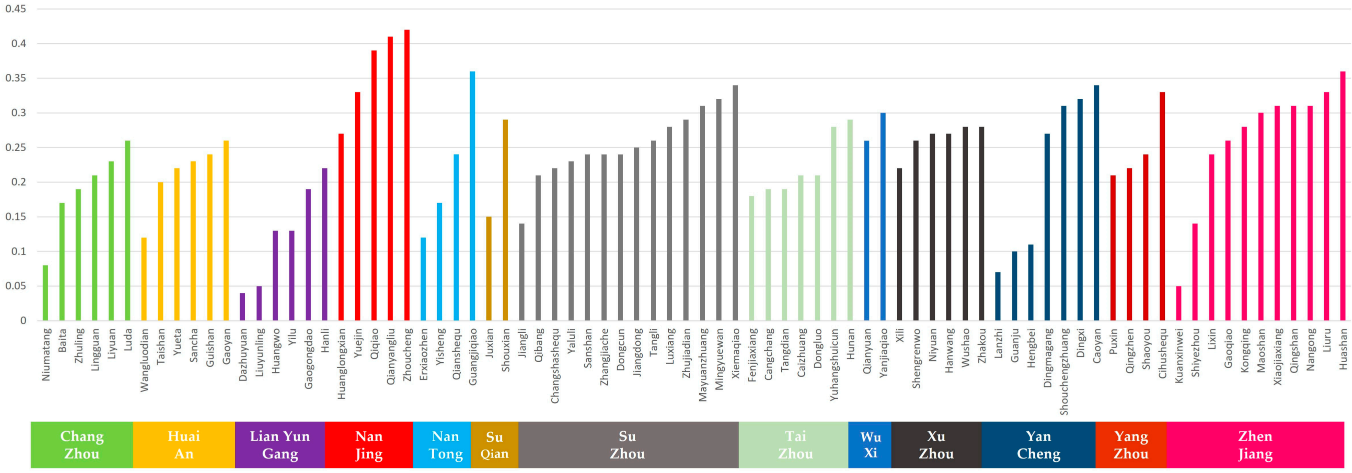

Figure 8. Analysis of the building density of traditional villages in different cities.

3.2. Types of Morphological Indicators

3.2.1. Distribution Analysis of Morphological Indicators (Y2 and Y3)

We utilized bar charts to present the spatial morphology indicators of traditional villages in Jiangsu, and to generate a distribution map of the aspect ratio and building density indicators (Figure 9). This allowed us to visually represent the distribution status of the morphological indicators of traditional villages in geospatial space, which can be utilized to summarize the characteristics of the spatial morphology and distribution patterns of traditional villages in Jiangsu.

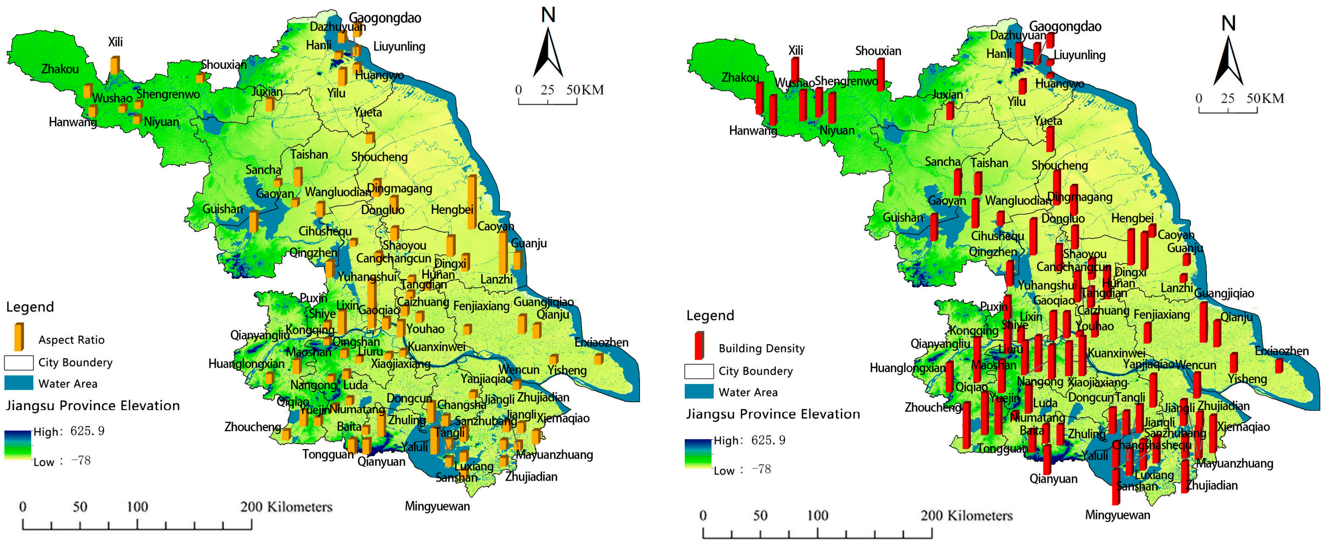

Figure 9. Bar charts of aspect ratio (Y2, **left**) and building density (Y3, **right**) indicators for traditional villages in Jiangsu.

3.2.2. Spatial Characteristics of Aspect Ratio (Y2)

From Figures 9 and 10, it can be seen that traditional village indicators in different regions exhibit cluster differentiation characteristics. Traditional villages in Nanjing and Zhenjiang have the lowest aspect ratios and the highest building density, with aspect ratios between 1.0 and 2.3 and building density values between 28% and 45%. The traditional villages in Suzhou, Wuxi, and Changzhou have the second-lowest aspect ratios and building density, with aspect ratios between 1.0 and 2.3. The aspect ratios and building density of traditional villages in Huai'an, Yangzhou, and Taizhou are moderate, with aspect ratios between 1.0 and 2.3 and building density values between 28% and 45%. The traditional villages in Xuzhou, Suqian, and Lianyungang, located within the green box in the figure, have the second-highest aspect ratios and the lowest building density. Their aspect ratios range from 1.0 to 2.2, and their building density values are less than 30%. The traditional villages in Yancheng and Nantong have the highest aspect ratios and a lower building density. These villages are located within the blue box in the figure, with aspect ratios higher than 2.0 and building density values lower than 40%. From this, it can be seen that the indicator characteristics of traditional villages in the Jiangsu region exhibit significant cluster characteristics and are highly correlated with geographical regional zoning.

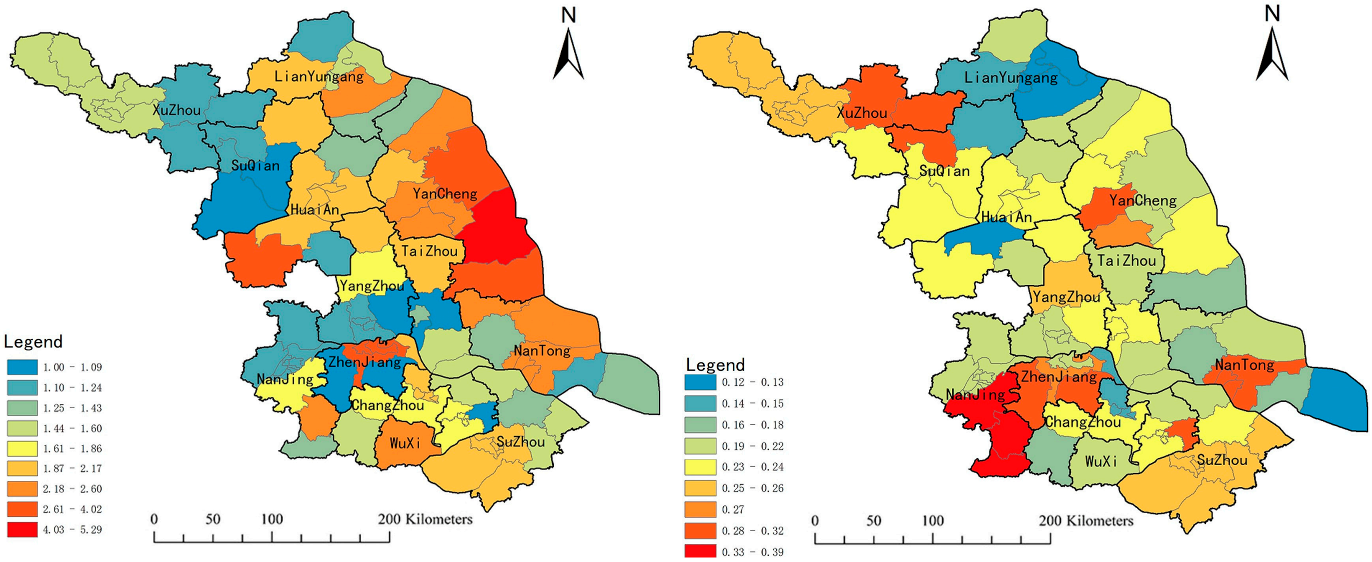

Figure 10. Spatial distribution map of aspect ratio (Y2, **left**) and building density (Y3, **right**).

The aspect ratio index is higher along the river and coastal areas and lower on the plains. Significant structural differences exist in the spatial distribution of the aspect ratio index in traditional villages in Jiangsu Province. Yancheng belongs to a high-aspect-ratio area, indicating that the spatial pattern of traditional villages has extremely significant strip-like characteristics, typical examples of which include the villages of Hengbei, Caoyan, Guanju, and Yilu. Nantong, Suzhou, Huai'an, the northern part of Zhenjiang, and Changzhou are located in areas with medium-to-high aspect ratios, indicating that the spatial pattern of this region has significant belt-like characteristics. The traditional villages in Nanjing and Zhenjiang have very high aspect ratios, with typical examples including the villages of Lixin, Gaoqiao, Kuanxinwei, and Shiye (Figure 8, right). Suzhou and Wuxi belong to areas with low aspect ratios, indicating a significant spatial cluster pattern, typical examples of which include Mingyue Bay and Yangjian Village.

3.2.3. Spatial Characteristics of the Building Density Indicator (Y3)

There have always been significant differences in the spatial form of traditional villages in different cities in Jiangsu Province. Spatial clustering analysis was carried out using the natural fracture method of ArcGIS, and the spatial morphology indicators were divided into five categories: high, medium–high, medium, medium–low, and low (Figure 9).

Nanjing belongs to the high-building-density area, while Zhenjiang, Suzhou, Suqian, and Xuzhou belong to the medium–high area. In contrast, Lianyungang belongs to the low-building-density area, while Changzhou belongs to the medium–low-building-density area, indicating that traditional villages in these two areas have a lower building density and higher vacancy rates.

Building density indicators are high in the south and west, while they are low in the north and east; the spatial distribution of the building density indicators of traditional villages in Jiangsu Province shows significant north–south and east–west differences. From the point of view of the three geographical regions of north, central, and south, the traditional villages show a gradual increase in building density from north to south. Traditional villages in the densely populated southern region of Jiangsu have the highest building density, with the highest density found in the hilly Taihu and Ningzhen areas. Central Jiangsu has rich lake resources (SDG6) and agricultural space (SDG2), the spatial layout of the settlements is relatively loose, and the spatial pattern of traditional villages tends to have low-density characteristics. The building density of traditional villages in northern Jiangsu is the lowest in the province, but there is also an east–west imbalance. Villages in western mountainous areas, such as the villages of Wushao and Niyuan in Xuzhou, have a high building density. The building density of villages along the eastern coast is relatively low, with typical examples including the villages of Liuyunling and Huangwo in Lianyungang (Figure 10, right).

3.3. Spatial Differences in Rural Sustainability

3.3.1. Rural Sustainable Development in Jiangsu from Multiple Perspectives

Figure 11 shows the distribution of six SDG-level scores for the environmental system. The SDG score represents the comprehensive development level of the six Sustainable Development Goal indicators in the environmental system dimension. The higher the SDG score in a rural area, the better its sustainability.

(1) Environmental System

Rural areas with suitable environmental sustainability are mainly concentrated in Lianyungang, Xuzhou, Suqian in northern Jiangsu, and Yancheng in eastern Jiangsu. Xuzhou, Lianyungang, and Suqian have shown advantages in terrestrial biodiversity (SDG15) and climate action (SDG13). Yancheng has performed excellently in underwater biological resource protection (SDG14), clean energy use (SDG7), and resource utilization (SDG12) (Figure 11).

(2) Economic System

The rural areas with good economic sustainability are mainly concentrated in Suzhou, Wuxi, and Changzhou in southern Jiangsu. These rural areas have developed economies, complete infrastructure, and a solid industrial foundation. Suzhou and Wuxi are among the leaders in employment economy (SDG8), industrial innovation (SDG9), poverty alleviation (SDG1), and strengthening partnerships (SDG17). The northern region of Jiangsu Province has performed well in terms of food self-sufficiency (SDG2) (Figure 12).

(3) Social System

The distribution of rural areas with good social sustainability is relatively flat, reflecting the overall good social governance capacity of Jiangsu Province. The most prominent aspect is Nantong’s outstanding performance in educational equality (SDG4). In rural areas such as Lianyungang, Huai’an, and Xuzhou in northern Jiangsu, there is a phenomenon of reducing inequality (SDG10) and numerous cold spots in health status (SDG3), indicating a significant wealth gap between urban and rural residents, the insufficient allocation of medical facilities, and the need for further improvement (Figure 13).

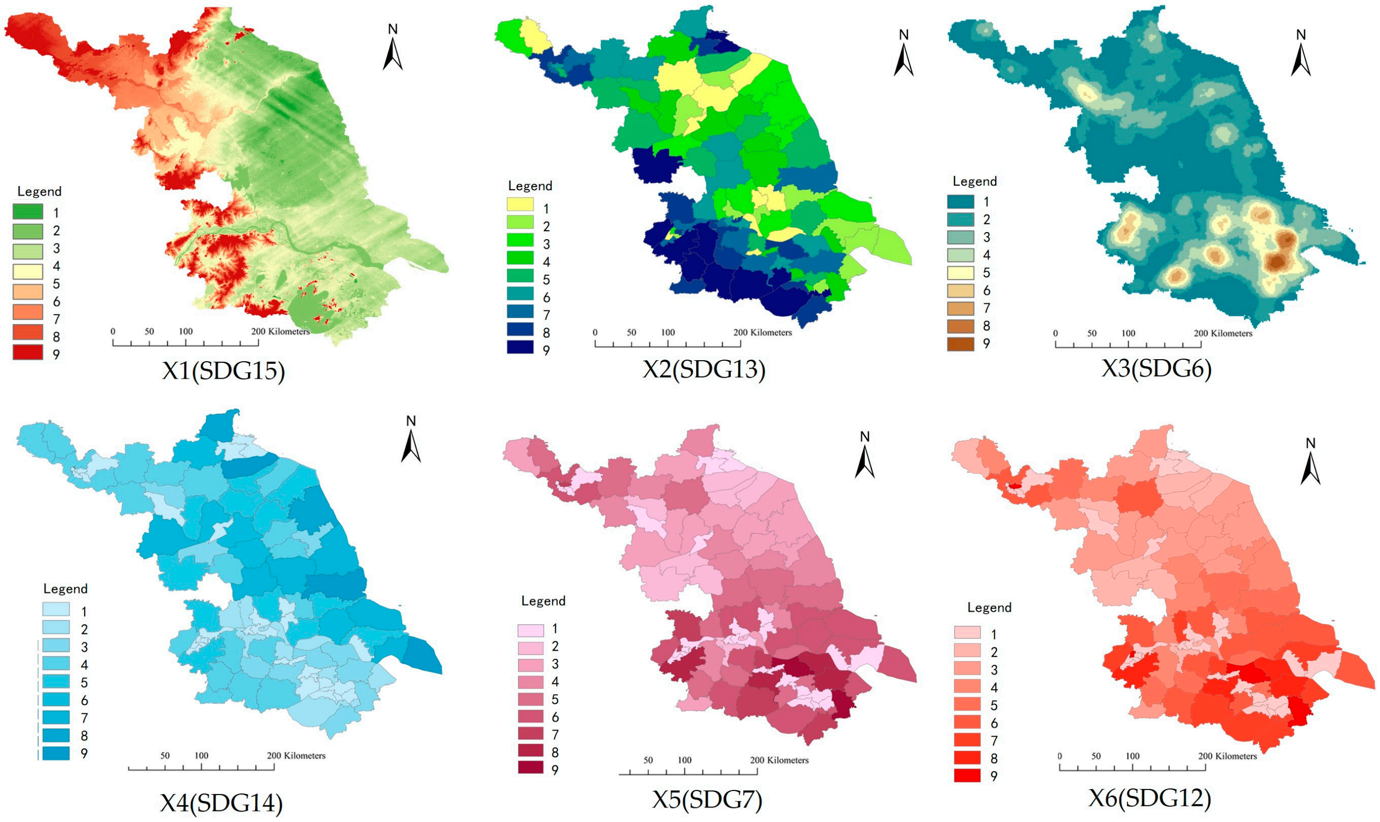

Figure 11. Spatial distribution maps of independent variables (environmental system).

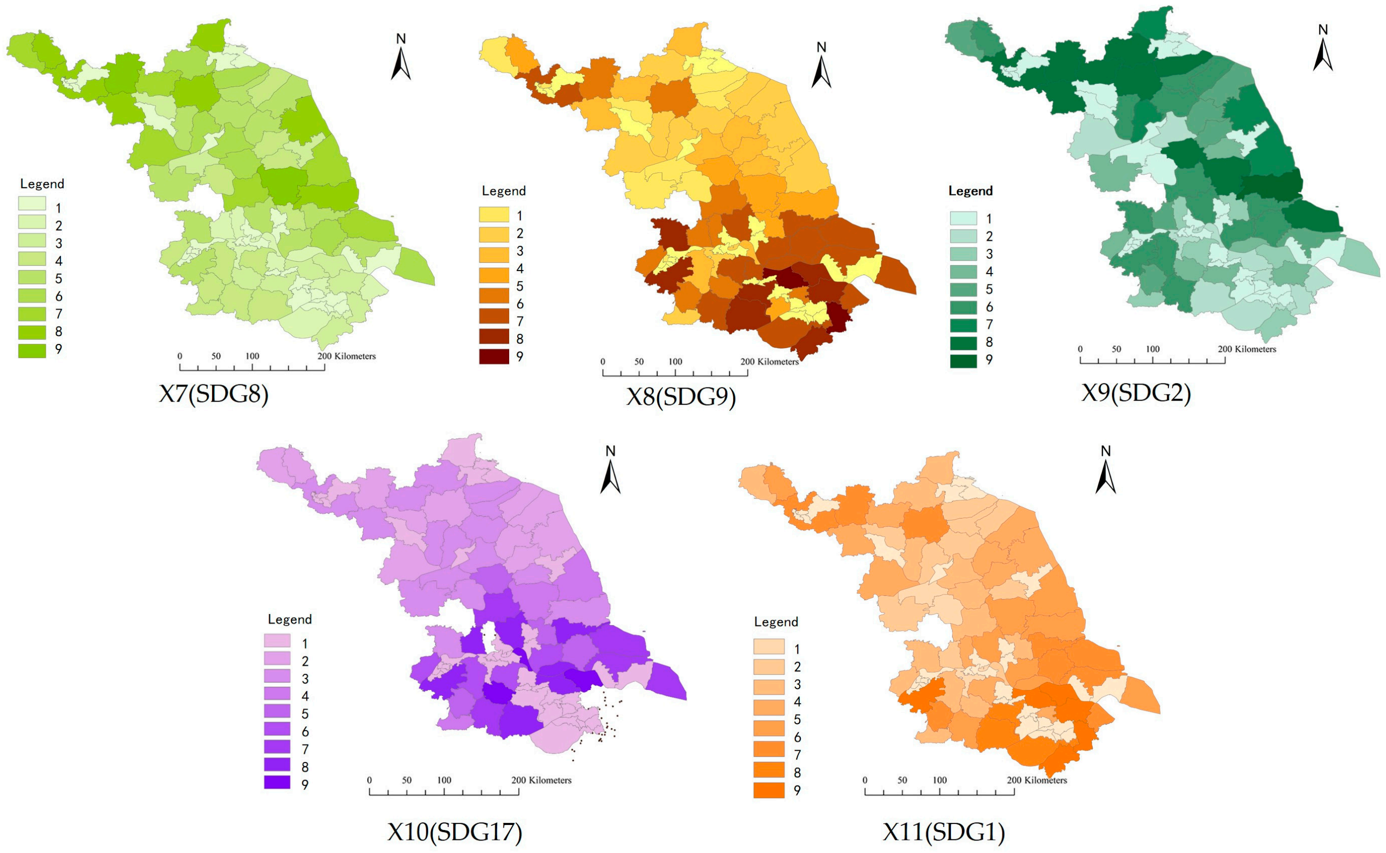

Figure 12. Spatial distribution maps of independent variables (economic system).

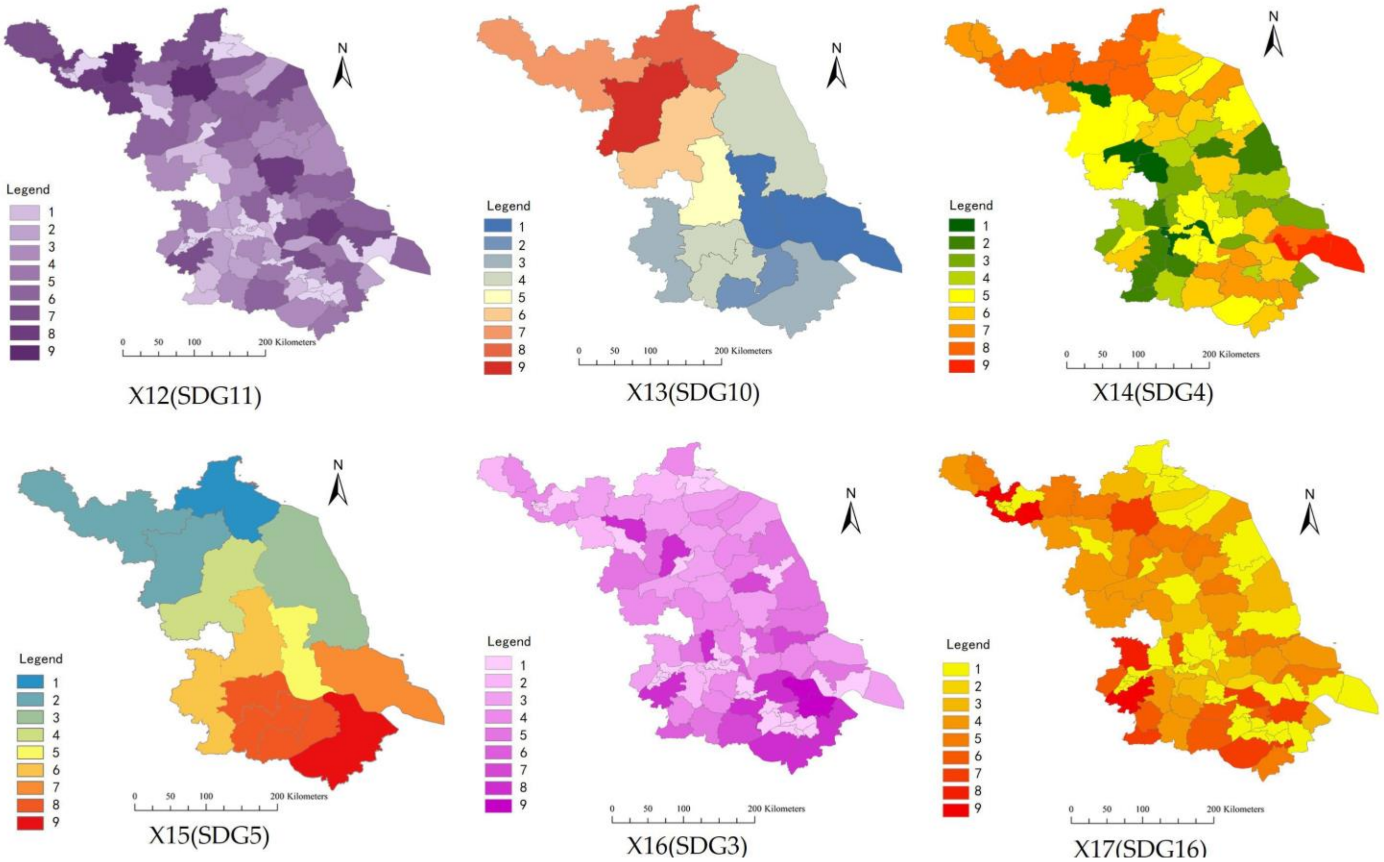

Figure 13. Spatial distribution maps of independent variables (social system).

3.3.2. Spatial Distribution of 17 SDGs

Figure 14 shows the spatial distribution of hot spots (high-sustainability areas) and cold spots (low-sustainability areas) for the 17 SDGs. (1) Environmental system: The forest coverage (SDG13) and terrestrial biodiversity (SDG15) of Lianyungang and Xuzhou at the border of northern Jiangsu Province and Shandong Province performed well. Yancheng's underwater species diversity (SDG 14) and forest coverage (SDG 13) in the coastal areas of Jiangsu Province are more prominent due to their emphasis on biodiversity conservation and low-carbon development. Nanjing and Changzhou, located at the borders of southern Jiangsu Province and Anhui Province (with high-density forest areas), have good environmental system performances but must improve their underwater species protection (SDG14). (2) Economic system: Many cold regions in northern Jiangsu, especially Lianyungang and Xuzhou, are lagging in terms of economic sustainability. The "Su-Xi-Chang" metropolitan area and the "Ning-Zhen-Yang" metropolitan area in southern Jiangsu have developed economies, and many hot spots are nearby. (3) Social system: Many SDG10 cold spots in Lianyungang and Xuzhou in northern Jiangsu indicate a significant wealth gap between urban and rural residents. The SDG16 cold spot in the northern region of Jiangsu Province, adjacent to Shandong Province, indicates the necessity of improving social welfare and public safety.

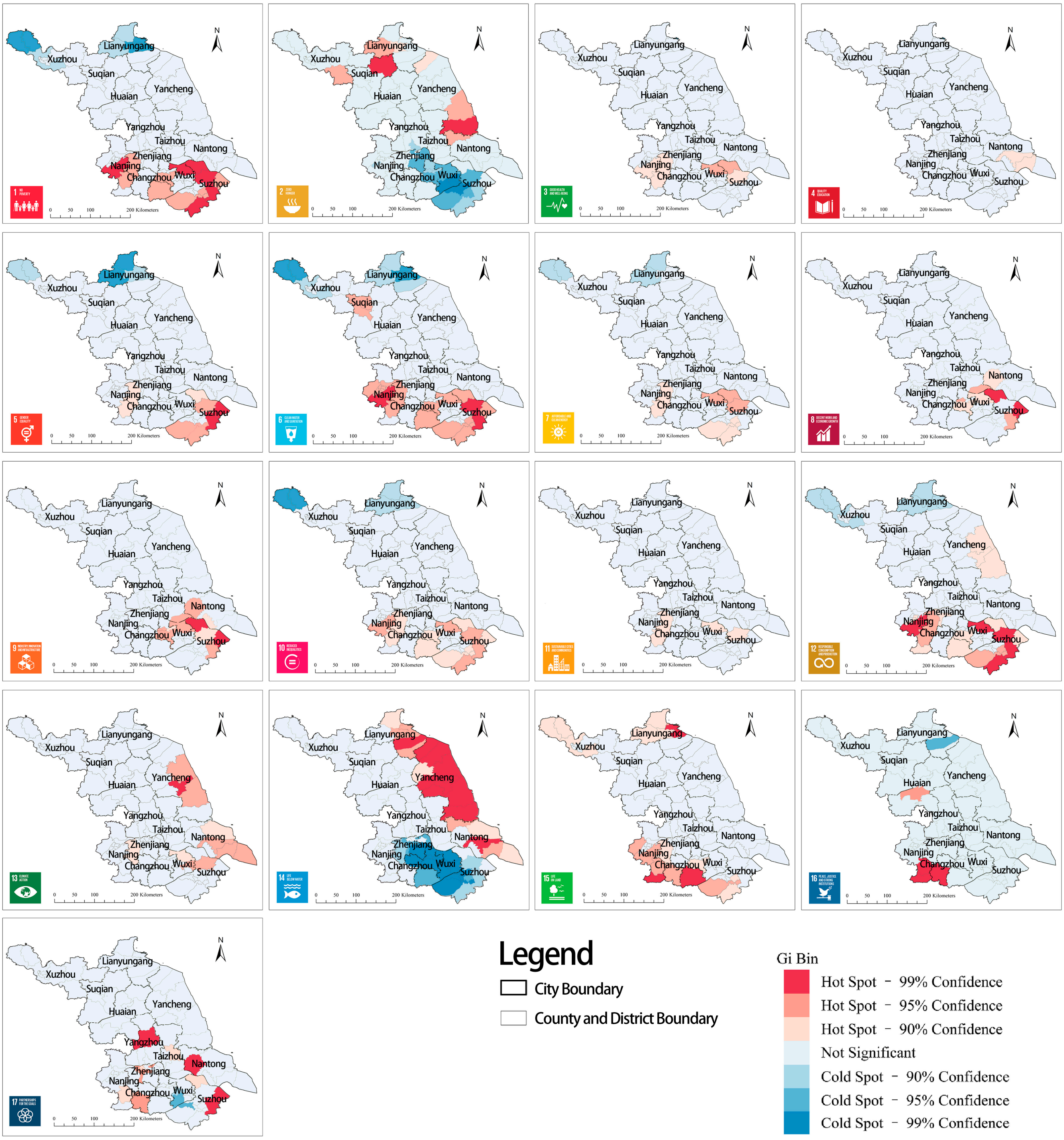

Figure 14. Analysis of the spatial distribution of hot spots (high-sustainability areas) and cold spots (low-sustainability areas) for the 17 SDGs.

3.4. Influencing Factors and Impact Mechanisms

3.4.1. The Importance and Nature of Factors

This section discusses the second question (which rural sustainability factors influence the generation and development of spatial morphological characteristics of traditional villages) through GeoDetector. After importing the dependent (Figure 11) and independent variables (Figure 12), the software outputs indicator values q (Xi) and q ($Xi \cap Xj$) to represent the direct and indirect effects of the factors, respectively. In addition, the software outputs factor interaction types, including nonlinear weakening, single nonlinear weakening, two-factor enhancement, and nonlinear enhancement, which are used to determine whether the factor interaction effects are antagonistic or synergistic (Table 2).

Table 2. Variable indicator correlation test table.

SDG Type	**Code**	**Y1**		**Y2**		**Y3**	
		q	*p*	*q*	*p*	*q*	*p*
SDG15—Life on Land	X1(SDG15)	0.02	0.00	0.09	0.00	0.12	0.00
SDG13—Climate Action	X2(SDG13)	0.27	0.00	0.21	0.00	0.29	0.00
SDG6—Clean Water and Sanitation	X3(SDG6)	0.01	0.004	0.01	0.21	0.03	0.00
SDG14—Life Below Water	X4(SDG14)	0.35	0.00	0.26	0.00	0.28	0.00
SDG7—Affordable and Clean Energy	X5(SDG7)	0.27	0.00	0.21	0.00	0.29	0.00
SDG12—Responsible Consumption and Production	X6(SDG12)	0.02	0.00	0.01	0.13	0.01	0.00
SDG8—Decent Work and Economic Growth	X7(SDG8)	0.18	0.00	0.18	0.00	0.09	0.00
SDG9—Industry, Innovation, and Infrastructure	X8(SDG9)	0.23	0.00	0.08	0.00	0.06	0.00
SDG2—Zero Hunger	X9(SDG2)	0.12	0.00	0.19	0.00	0.30	0.00
SDG17—Partnerships for The Goals	X10(SDG17)	0.26	0.00	0.03	0.00	0.16	0.00
SDG1—No Poverty	X11(SDG1)	0.27	0.00	0.21	0.00	0.29	0.00
SDG11—Sustainable Cities and Communities	X12(SDG11)	0.06	0.00	0.12	0.00	0.07	0.00
SDG10—Reduced Inequalities	X13(SDG10)	0.20	0.00	0.09	0.00	0.04	0.00
SDG4—Quality Education	X14(SDG4)	0.09	0.00	0.09	0.00	0.11	0.00
SDG5—Gender Equality	X15(SDG5)	0.05	0.00	0.12	0.00	0.10	0.00
SDG3—Good Health and Well-being	X16(SDG3)	0.09	0.00	0.08	0.00	0.08	0.00
SDG16—Peace, Justice, and Strong Institutions	X17(SDG16)	0.13	0.00	0.28	0.00	0.18	0.00

3.4.2. The Spatial Effects of Direct Influencing Factors

For the spatial distribution of traditional villages, the mean value of the direct influence of each factor is 0.16. The driving forces of Life below Water (SDG14), No Poverty (SDG1), Climate Action (SDG13), Affordable and Clean Energy (SDG7), Partnerships for the Goals (SDG17), Industry, Innovation, and Infrastructure (SDG9), Reduced Inequalities (SDG10), and Decent Work and Economic Growth (SDG8) are all higher than the mean value. Life below Water (SDG14), No Poverty (SDG1), and Climate Action (SDG13) have the most significant influence, followed by Affordable and Clean Energy (SDG7) and Partnerships for the Goals (SDG17), which are well ahead of the other factors. This indicates that traditional villages tend to be distributed in areas with abundant aquatic resources, good economic foundations, and good environmental quality. It is worth noting that the impacts of Life on Land (SDG15) and Responsible Consumption and Production (SDG12) are fragile, and the direct effect of Clean Water and Sanitation (SDG6) is only moderately statistically significant.

For the spatial distribution of the traditional villages' aspect ratio indicator, the mean value of the direct influence of each factor is 0.13. The drivers of Peace, Justice, and Strong Institutions (SDG16), Life below Water (SDG14), Climate Action (SDG13), No Poverty (SDG1), Affordable and Clean Energy (SDG7), Decent Work and Economic Growth (SDG8), and Zero Hunger (SDG2) are above the mean value. Peace, Justice, and Strong Institutions (SDG16) and Life Bellow Water (SDG14) both lead the pack in terms of direct influence, while Responsible Consumption and Production (SDG12) and Partnerships for the Goals (SDG17) rank last. This shows that rural areas with high aspect ratios have greater underwater biodiversity, more substantial governmental administrative power, and more clean energy. This may be due to their proximity to the seaside or rivers, adopting a robust government model for management, and investing in the construction of more wind or photovoltaic facilities to supply energy.

For the spatial distribution of the traditional villages' building density indicator, the mean value of the direct influence of each factor is 0.14. The driving forces of Zero Hunger (SDG2), Climate Action (SDG13), Affordable and Clean Energy (SDG7), No Poverty (SDG1), Life below Water (SDG14), and Partnerships for the Goals (SDG17) are above the mean value. Zero Hunger (SDG2), No Poverty (SDG1) and Climate Action (SDG13) are far ahead in terms of direct influence, while Clean Water and Sanitation (SDG6), Responsible Consumption and Production (SDG12), and Reduced Inequalities (SDG10) rank last. This shows that a high-density built environment is correlated with faster economic development and higher green coverage.

3.4.3. Interaction Detector for Driving Factors

The overall distribution pattern of the villages exhibits a significant synergistic effect when different factors work together, resulting in two-factor enhancement and nonlinear enhancement. The mean value of the interaction effect is 0.33. Within the interaction, SDG14 and SDG7 were identified as the key super-interacting factors. Notably, the factor pairs of SDG4 ∩ SDG1, SDG4 ∩ SDG13, SDG4 ∩ SDG7, and SDG14 ∩ SDG17 comprised the top four in terms of interaction effect (Table 3).

Table 3. Interactive detector for the overall distribution index of traditional villages.

SDG	15	13	6	14	7	12	8	9	2	17	1	11	10	4	5	3	16
15	0.02																
13	0.35	0.27															
6	0.05	0.32	0.01														
14	0.40	0.41	0.40	0.35													
7	0.35	0.27	0.32	0.41	0.27												
12	0.05	0.31	0.04	0.38	0.31	0.02											
8	0.28	0.46	0.23	0.46	0.46	0.21	0.18										
9	0.28	0.49	0.28	0.49	0.49	0.25	0.42	0.23									
2	0.19	0.42	0.18	0.46	0.42	0.15	0.34	0.43	0.12								
17	0.31	0.50	0.31	0.51	0.50	0.29	0.42	0.39	0.41	0.26							
1	0.35	0.27	0.32	0.41	0.27	0.31	0.46	0.49	0.42	0.50	0.27						
11	0.12	0.43	0.12	0.46	0.43	0.10	0.32	0.42	0.28	0.47	0.43	0.06					
10	0.24	0.48	0.24	0.48	0.48	0.23	0.39	0.31	0.37	0.41	0.48	0.39	0.20				
4	0.16	0.51	0.15	0.47	0.51	0.14	0.36	0.44	0.32	0.44	0.51	0.25	0.40	0.09			
5	0.12	0.45	0.11	0.46	0.45	0.09	0.35	0.39	0.30	0.41	0.45	0.21	0.42	0.29	0.05		
3	0.14	0.49	0.15	0.46	0.49	0.12	0.37	0.39	0.32	0.42	0.49	0.32	0.36	0.34	0.38	0.09	
16	0.19	0.47	0.20	0.46	0.47	0.17	0.35	0.49	0.29	0.45	0.47	0.34	0.45	0.38	0.36	0.33	0.13

The interactions between factor pairs showed two-factor and nonlinear enhancement for the village aspect ratio index, which decreased to 66.67%. The mean value of the interaction effect is 0.44. It is worth noting that Climate Action (SDG13), Life below Water (SDG14), Affordable and Clean Energy (SDG7), No Poverty (SDG1), and Zero Hunger (SDG2) are super-interacting factors; SDG8 ∩ SDG13, SDG8 ∩ SDG14, SDG8 ∩ SDG7, SDG1 ∩ SDG8, SDG2 ∩ SDG 14, and SDG11 ∩ SDG14 comprised the top six interaction forces (Table 4).

Table 4. Interactive detector of aspect ratio indicators for traditional villages.

SDG	15	13	6	14	7	12	8	9	2	17	1	11	10	4	5	3	16
15	0.12																
13	0.43	0.29															
6	0.18	0.36	0.03														
14	0.34	0.40	0.36	0.28													
7	0.43	0.29	0.36	0.40	0.29												
12	0.14	0.32	0.06	0.32	0.32	0.01											
8	0.41	0.77	0.19	0.76	0.77	0.14	0.09										
9	0.28	0.63	0.13	0.58	0.63	0.10	0.46	0.06									
2	0.48	0.73	0.36	0.76	0.73	0.34	0.57	0.64	0.30								
17	0.36	0.60	0.26	0.66	0.60	0.20	0.63	0.35	0.65	0.16							
1	0.43	0.29	0.36	0.40	0.29	0.32	0.77	0.63	0.73	0.60	0.29						
11	0.32	0.61	0.17	0.76	0.61	0.11	0.52	0.48	0.62	0.57	0.62	0.07					
10	0.30	0.71	0.11	0.66	0.71	0.08	0.50	0.33	0.58	0.45	0.71	0.45	0.04				
4	0.34	0.74	0.23	0.75	0.74	0.15	0.56	0.43	0.65	0.62	0.75	0.41	0.45	0.11			
5	0.39	0.71	0.19	0.68	0.71	0.13	0.48	0.59	0.64	0.64	0.70	0.33	0.47	0.57	0.10		
3	0.32	0.72	0.16	0.59	0.72	0.12	0.54	0.58	0.60	0.64	0.71	0.47	0.43	0.65	0.40	0.08	
16	0.30	0.63	0.17	0.61	0.63	0.13	0.48	0.54	0.56	0.64	0.63	0.52	0.54	0.58	0.53	0.57	0.08

The interactions between different and super-interacting factors are identical for the village building density index. Still, there are differences in the composition of factor pairs and their interaction effects. The mean value of the interaction effect is 0.42. Among the factor pairs, Climate Action (SDG13), Quality Education (SDG14), Affordable and Clean Energy (SDG7), and No Poverty (SDG1) are the super-interacting factors. Among them, SDG3 ∩ SDG13, SDG3∩ SDG7, SDG3 ∩ SDG1, SDG10 ∩ SDG13, SDG10 ∩ SDG7 and SDG10 ∩ SDG1 comprised the top six in terms of value added (Table 5).

Table 5. Interactive detector for building density indicators in traditional villages.

SDG	15	13	6	14	7	12	8	9	2	17	1	11	10	4	5	3	16
15	0.09																
13	0.27	0.21															
6	0.13	0.28	0.01														
14	0.34	0.41	0.37	0.26													
7	0.27	0.21	0.28	0.41	0.21												
12	0.12	0.26	0.04	0.30	0.26	0.01											
8	0.36	0.62	0.26	0.64	0.62	0.22	0.18										
9	0.25	0.59	0.19	0.63	0.59	0.13	0.48	0.08									
2	0.35	0.72	0.25	0.67	0.72	0.22	0.43	0.53	0.19								
17	0.22	0.60	0.11	0.54	0.60	0.09	0.54	0.37	0.43	0.03							
1	0.27	0.22	0.28	0.41	0.22	0.26	0.62	0.59	0.71	0.59	0.21						
11	0.27	0.69	0.19	0.58	0.69	0.16	0.48	0.54	0.35	0.46	0.69	0.12					
10	0.36	0.73	0.18	0.72	0.73	0.14	0.57	0.35	0.62	0.52	0.73	0.61	0.09				
4	0.29	0.71	0.16	0.61	0.71	0.13	0.54	0.51	0.45	0.55	0.71	0.33	0.63	0.09			

Table 5. *Cont.*

SDG	15	13	6	14	7	12	8	9	2	17	1	11	10	4	5	3	16
5	0.28	0.70	0.17	0.66	0.70	0.17	0.48	0.58	0.47	0.47	0.70	0.42	0.51	0.64	0.12		
3	0.26	0.80	0.14	0.66	0.80	0.12	0.44	0.53	0.48	0.50	0.79	0.37	0.45	0.69	0.35	0.08	
16	0.38	0.69	0.35	0.69	0.69	0.31	0.54	0.67	0.53	0.72	0.69	0.47	0.69	0.70	0.52	0.48	0.27

4. Discussion

4.1. High Spatial Pattern Heterogeneity, High Correlation, and Clustering of Morphological Indicators

We found that the spatial pattern of traditional villages in Jiangsu Province shows solid heterogeneity, the spatial morphological indicators have a high degree of correlation and aggregation, and a typical morphological indicator partition exists. The morphological indicator model can better explore the spatial differences between villages and different cities. In addition, it can be combined with the spectral clustering algorithm for partitioning and manual calibration, and then superimposed on the natural geography and cultural circle differences, effectively dividing the traditional village protection zoning in Jiangsu Province. These new findings and opinions are integral to the original research conclusions of this paper, providing valuable additions to the theories related to the protection and utilization of traditional villages.

From a theoretical perspective, the morphology index model can effectively quantify and identify the geographical differences between traditional villages, accurately determine their spatial patterns, and provide researchers, government decisionmakers, and the public with a new method to study their morphology, conservation, and utilization. From a practical perspective, this paper's methods and conclusions apply to Jiangsu and provide valuable decision-making references for policy designs in traditional village-rich areas such as Anhui, Zhejiang, and Shanxi. In recent years, the number and scale of traditional villages in these provinces have ranked among the top in China, and, like in Jiangsu, tremendous emphasis is being placed on protecting traditional villages [57,58].

4.2. Interpreting the Correlation Mechanism between Traditional Villages' Spatial Morphology and Sustainability (Driving Mechanisms)

Based on the ranking and average values of factor strengths, as well as a comprehensive consideration of the strength of factor interactions, driving factors were categorized into three groups: "key factors", "important factors", and "supporting factors". The "key factors" are dominated by direct forces, with the strength of the factors ranking in the top three. The income of urban residents and its changes, Life below Water (SDG14), Climate Action (SDG13), and No Poverty (SDG1) are the key factors. The direct forces and the interaction forces of the "important factors" work simultaneously, and the direct force must be greater than the average value, or else a reasonably strong interaction force is needed. Partnerships for the Goals (SDG17), Affordable and Clean Energy (SDG7), and Recent Work and Economic Growth (SDG8) are important factors. "Supporting factors" have weak direct forces and are below average. It is worth noting that the interaction forces of auxiliary factors such as Zero Hunger (SDG2) and Peace, Justice, and Strong Institutions (SDG16) are also more prominent.

4.3. Policy Design Value

Most traditional villages in cities in Jiangsu Province belong to "economic-oriented" policy areas, mainly distributed in Nanjing, Zhenjiang, Suzhou, Wuxi, and Changzhou. The first priority here is to strengthen Sustainable Community Building (SDG11), protect its low aspect ratio and high-density building environment, provide overall protection for deep houses, preserve street corridors, provide fire monitoring for building clusters, supplement service facilities (SDG3), and adopt Affordable and Clean Energy (SDG7). The economy in this region is more developed, and it is necessary to accelerate the formulation and refinement of traditional village protection policies to provide a sustainable protection model that can be replicated and promoted by coupling traditional villages with rural communities [8]. The second is fully utilizing the regional industrial innovation environment (SDG9), rich historical resources, and sufficient protection funds (SDG1). Suzhou has successfully issued, formulated, and implemented the Guiding Opinions on Strengthening Protection, the Utilization and Development of Urban Traditional Villages, the Suzhou Ancient Village Protection Regulations, and the Suzhou Traditional Village Protection and Renewal Technical Guidelines. Through the integration of industrial innovation resources (SDG9), these have become part of the first batch of replicable traditional village protection and utilization experience lists chosen by the Ministry of Housing and Urban–Rural Development. The focus of future work will be to steadily promote the effective implementation of relevant policies and plans. Thirdly, attention should be paid to protecting environmental quality (SDG12). Suzhou, Wuxi, Changzhou, Nanjing, and Zhenjiang have excellent industrial foundations. At the same time, the towns and villages surrounding traditional villages are more densely industrialized, which conflicts with the protection of traditional villages. This paper suggests that to accelerate the development of traditional village protection demonstration zone planning, the resources and interference factors related to traditional villages must be systematically sorted out, and the experience must be replicable as soon as possible.

The “social-oriented” policy area is a relatively mixed area, mainly composed of Nantong, Yancheng, Xuzhou, and Suqian, with a high aspect ratio of the village spatial form, an interprovincial border location, and distinctive infrastructure levels. Firstly, it is necessary to fully utilize environmentally friendly, green, and low-carbon spatial forms and residential patterns, focusing on protecting fan-shaped or strip-shaped contour forms and maintaining the spatial pattern of buildings facing mountains and water, along with streets parallel to rivers. Secondly, Affordable and Clean Energy (SDG7) technologies such as wind power, photovoltaics, and natural gas are recommended, improving the living environment of traditional villages from the perspective of energy self-sufficiency and preventing the return to regional poverty (SDG1). Thirdly, there is a need to reduce urban–rural inequality (SDG10) and carry out a program to cultivate farmers and inheritors of handicrafts. By protecting historic industrial sites and constructing and operating related cultural sites, we can promote the active inheritance of traditional handicrafts, thereby promoting the revival of traditional villages. Fourthly, the establishment of partnerships should be increased (SDG17), public participation in traditional villages should be increased, and we should encourage and support government personnel, university teachers and students, scientific research institutions, villagers, non-governmental organizations, and other individuals from all walks of life to form traditional village protection alliances, holding regular meetings to discuss and make decisions on significant issues related to the development of traditional villages [41].

Huaian, Yangzhou, Taizhou, and Lianyungang belong to the “Environmental Oriented” policy areas, with excellent ecological foundations. Efforts to protect traditional villages are accelerating, and there is a certain contradiction between environmental management, village protection, and economic development. To improve the protection of traditional villages, it is necessary to strengthen the policy design of systematic innovation. The first step is to prioritize the environment and protect the topography and environmental characteristics of mountains, lakes, and oceans, which are the foundation for achieving the goals of safeguarding terrestrial and underwater organisms (SDG15, SDG14). The cultivable farmland space and agricultural facilities in this rural area should be strictly protected to achieve the goal of eradicating hunger (SDG2) while focusing on the construction of low-density and low-intensity spatial forms, which are identifiable features that distinguish the “environment-oriented” policy area from other areas. The second step is to actively implement digital protection of traditional villages, enhance the ability to achieve Partnerships for the Goals (SDG17), implement digital planning, digital operation, and digital monitoring, and use technologies such as big data, cloud computing, and the

Internet of Things to establish a comprehensive digital information monitoring platform for traditional villages and unify the integration of village appearance data, tourism data, and economic development data. Thirdly, we should aim to compensate for the development opportunities lost due to environmental protection, achieve the goal of Decent Work and Economic Growth (SDG8), accelerate the implementation of commercial formats, and promote the development of the tertiary industry. The building density of villages in this area is low, making it suitable for building insertion and expansion, culture and entrepreneurial enterprises, increasing population mobility, and promoting the development of the tourism industry.

5. Conclusions

This study quantitatively examined the spatial form characteristics of traditional villages and the sustainable development of villages in Jiangsu Province. We empirically investigated the influencing factors and their interaction effects, elucidating the driving mechanisms of sustainable development in rural spatial forms, and proposing targeted optimization policies and measures. In recent years, the sustainable development of rural areas has become a common concern globally, with China serving as a typical and representative example. Using the morphology index calculation model and ArcGIS tools, we conducted an empirical study on the spatial morphology differentiation of 80 representative traditional villages in Jiangsu Province and the sustainable driving factors behind them. Our findings are as follows:

(1) The spatial distribution patterns and indicator characteristics of traditional villages in Jiangsu Province are of great significance in revealing the operating mechanisms of sustainable rural development in highly urbanized areas. The spatial heterogeneity, clustering, and autocorrelation are intertwined with the macroeconomic, ecological environment, industrial development, population clustering, and cultural protection policies, with significant differences in driving forces and complex interaction effects. In combining the SDGs indicator system with the rural Sustainable Development Goals and the problems that they face as guiding principles, and based on the operational rules of spatial distribution pattern differences and driving mechanisms of morphological characteristics, differentiated policy design and adjustment measures can significantly improve the accuracy and synergy of policies, with important practical significance and theoretical value.

(2) This study evaluated the sustainable development of traditional villages from a composite perspective of "Morphology–Environment–Economy–Society", emphasizing the improvement of different sustainable policy designs based on sustainability endowments, including form, environment, society, and economy. This article provides a new technical framework for studying the interaction mechanism between rural sustainable development and spatial form from a theoretical perspective, which can help scholars to grasp and reveal the spatial patterns and driving factors of village spatial form characteristics and promote the sustainable development of contiguous traditional Chinese village areas. Specifically, the high-density and low-aspect-ratio rural form in the southern region (where rural industries are concentrated) promotes good economic sustainability in rural areas but also leads to poor environmental performance. The rural areas in the southwest and north (high-density forest areas) have medium density and high aspect ratios, and the lack of agricultural space and external connections affects their social performance. The main focus here is on poverty reduction and urban cooperation. The central and northern lakeside areas and the eastern coastal areas (important ecological protection areas) have a low density and high aspect ratios, which have helped achieve excellent environmental performances but also led to contradictions in the ecological, economic, and social performances. Reducing carbon emissions and protecting terrestrial and underwater biodiversity are crucial for the sustainability of rural environments. Promoting cooperation between cities and improving industrial development are conducive to the sustainable devel-

opment of the rural economy. Improving social welfare and agricultural development levels contributes to the sustainability of rural society.

(3) The sustainable mechanisms of traditional village spatial patterns were comprehensively and systematically revealed through the integration of morphological indicator analysis, kernel density, and GeoDetector. This included a detailed analysis of the spatial patterns and performance of traditional village spatial layouts, as well as the spatial and interactive effects of different factors. This is a brand-new exploration and discovery. The results indicate that the impacts of various factors differ significantly. For example, Life below Water (SDG14), Climate Action (SDG13), and No Poverty (SDG1) are the most prominent, followed by Partnerships for the Goals (SDG17), Affordable and Clean Energy (SDG7), and Recent Work and Economic Growth (SDG8).

(4) This study was not limited to the analysis of the spatial form characteristics of traditional villages; rather, based on the assessment of rural sustainability indicators (SDGs), it also divided traditional villages into three types of policy zones, economic-oriented, social-oriented, and environmental-oriented, proposing differentiated zoning, planning, and multiple policies to manage the sustainable construction of rural areas.

There are still some limitations to this study. (1) Due to the limited data and information, we only considered the influence of the spatial distribution, aspect ratio, and building density indicators of traditional villages in the performance assessment, without considering the spatial heterogeneity of other morphological indicators. The analysis model may impact the accuracy of the analysis results. (2) This paper is based on an interregional inter-village comparative study and does not provide in-depth analyses of the spatial patterns of traditional villages in individual cities within Jiangsu, particularly in key cities. This limitation restricts the broad application of the results to some extent. (3) This study showed that methods based on morphological indicators and GeoDetector could become new tools for analyzing the spatial morphology of traditional villages and assessing the sustainability of villages. However, there is still room for improvement in the accumulation of architectural morphology data at multiple spatial scales (national, regional, and urban), selecting factors for calculating the morphology index, optimizing spectral clustering methods, etc. We invite other scholars to carry out case studies and empirical research so that they can provide technical support for the government to formulate policies for the protection of traditional villages. This study took the sustainability assessment of villages as a starting point; it focused on the regional analysis and planning of the spatial patterns of traditional villages, expanding the field of rural research from the traditional one-dimensional analysis of spatial patterns, natural ecology, history, culture, and socioeconomics to a multidimensional analysis, which entailed a certain degree of theoretical innovation.

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Appendix A

Table A1. Shape index of traditional villages in Jiangsu.

Order	City	Traditional Village Name	Shape Index	
			Aspect Ratio Value (λ)	Building Density Value (M)
1	Lianyungang	Dazhuyuan	1.41	0.04
2	Lianyungang	Liuyunling	1.57	0.05
3	Zhenjiang	Kuanxinwei	2.50	0.05
4	Yancheng	Lanzhi	6.40	0.07
5	Changzhou	Niumatang	1.12	0.08
6	Yancheng	Guanju	2.60	0.1
7	Yancheng	Hengbei	8.10	0.11
8	Nantong	Erxiaozhen	1.41	0.12
9	Huai'an	Wangluodian	2.15	0.12
10	Lianyungang	Huangwo	2.07	0.13
11	Lianyungang	Yilu	2.57	0.13
12	Suzhou	Jiangli	1.62	0.14
13	Zhenjiang	Shiyezhou	3.60	0.14
14	Suqian	Juxian	1.94	0.15
15	Nantong	Yisheng	1.20	0.17
16	Changzhou	Baita	1.22	0.17
17	Taizhou	Fenjiaxiang	1.32	0.18
18	Taizhou	Cangchang	1.10	0.19
19	Taizhou	Tangdian	1.20	0.19
20	Lianyungang	Gaogongdao	1.41	0.19
21	Changzhou	Zhuling	3.71	0.19
22	Huai'an	Taishan	2.70	0.2
23	Yangzhou	Puxin	1.20	0.21
24	Suzhou	Qibang	1.45	0.21
25	Taizhou	Caizhuang	1.50	0.21
26	Taizhou	Dongluo	2.00	0.21
27	Changzhou	Lingguan	2.42	0.21
28	Lianyungang	Hanli	1.03	0.22
29	Huai'an	Yueta	1.40	0.22
30	Suzhou	Changshashequ	1.67	0.22
31	Xuzhou	Xili	2.50	0.22
32	Yangzhou	Qingzhen	2.50	0.22
33	Huai'an	Sancha	1.00	0.23
34	Changzhou	Liyuan	1.32	0.23
35	Suzhou	Yaluli	4.00	0.23
36	Suzhou	Sanshan	1.37	0.24
37	Yangzhou	Shaoyou	1.49	0.24
38	Suzhou	Zhangjiache	1.50	0.24

Table A1. *Cont.*

Order	City	Traditional Village Name	Shape Index	
			Aspect Ratio Value (λ)	Building Density Value (M)
39	Zhenjiang	Lixin	1.79	0.24
40	Nantong	Qianshequ	2.21	0.24
41	Huai'an	Guishan	3.10	0.24
42	Suzhou	Dongcun	3.20	0.24
43	Suzhou	Jiangdong	1.39	0.25
44	Xuzhou	Shengrenwo	1.07	0.26
45	Huai'an	Gaoyan	1.14	0.26
46	Changzhou	Luda	1.25	0.26
47	Suzhou	Tangli	2.22	0.26
48	Wuxi	Qianyuan	2.29	0.26
49	Zhenjiang	Gaoqiao	7.45	0.26
50	Xuzhou	Niyuan	1.18	0.27
51	Nanjing	Huanglongxian	1.50	0.27
52	Xuzhou	Hanwang	1.56	0.27
53	Yancheng	Dingmagang	2.41	0.27
54	Zhenjiang	Kongqing	1.00	0.28
55	Xuzhou	Wushao	1.03	0.28
56	Suzhou	Luxiang	1.45	0.28
57	Taizhou	Yuhangshuicun	1.55	0.28
58	Xuzhou	Zhakou	1.90	0.28
59	Taizhou	Hunan	1.00	0.29
60	Suqian	Shouxian	1.21	0.29
61	Suzhou	Zhujiadian	1.37	0.29
62	Zhenjiang	Maoshan	1.00	0.3
63	Wuxi	Yanjiaqiao	1.09	0.3
64	Zhenjiang	Xiaojiaxiang	1.00	0.31
65	Zhenjiang	Qingshan	1.22	0.31
66	Zhenjiang	Nangong	1.28	0.31
67	Suzhou	Mayuanzhuang	1.39	0.31
68	Yancheng	Shouchengzhuang	2.52	0.31
69	Suzhou	Mingyuewan	1.55	0.32
70	Yancheng	Dingxi	3.05	0.32
71	Yangzhou	Cihushequ	1.00	0.33
72	Zhenjiang	Liuru	1.09	0.33
73	Nanjing	Yuejin	1.32	0.33
74	Suzhou	Xiemaqiao	2.07	0.34
75	Yancheng	Caoyan	2.47	0.34
76	Zhenjiang	Huashan	1.00	0.36
77	Nantong	Guangjiqiao	2.78	0.36
78	Nanjing	Qiqiao	2.50	0.39

Table A1. *Cont.*

Order	City	Traditional Village Name	Shape Index	
			Aspect Ratio Value (λ)	Building Density Value (M)
79	Nanjing	Qianyangliu	2.22	0.41
80	Nanjing	Zhoucheng	1.44	0.42

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