

## Article

# Study on the Spatial-Temporal Characteristics and Divergence of Rural Human Settlement Quality of Mountainous Counties in Zhejiang, China

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**Abstract:** The rural human settlement is an important carrier for rural residents' production and living life, and its quality level is an important basis for judging the current living conditions of rural residents. This study aims to explore the spatial-temporal characteristics of the rural human settlement in mountainous counties of Zhejiang Province, as well the influencing factors, based on a constructed evaluation index system for a quality improvement in these areas. This study takes the rural human settlement of the mountainous counties in Zhejiang Province as the research object, constructs an evaluation index system of rural human settlement quality of these counties based on the current situation and development policies of Zhejiang Province, and evaluates the rural human settlement quality from 2016 to 2020. Further, spatial autocorrelation analysis, trend surface analysis, and other analysis methods are used to evaluate the results. The evaluation results were analyzed using spatial autocorrelation analysis and trend surface analysis, and the performance of each influencing factor and interaction force was detected using geographic probes. The study found that: (1) Overall, the quality of the rural human settlement in the mountainous counties of Zhejiang Province has been steadily improving over the past five years, and there is no obvious spatial correlation among counties, though the spatial development characteristics and development trend of the north is better than the south, and the east is better than the central areas. (2) Each subsystem also shows a steady increase and presents different spatial distribution characteristics. (3) The quality of the rural human settlement is significantly associated with policy orientation, the level of economic development, and landscape development characteristics. (4) The factors that currently have the greatest effect on the 26 counties include the level of agricultural modernization and economic development level, among which five groups of factors have an interactive effect. In sum, this study judged the development trend of rural human settlement quality and the main influencing factors in the mountainous counties of Zhejiang Province this year and provides a scientific basis for their improvement. It also provides research ideas for the evaluation and optimization of rural habitat quality in other mountainous counties in China.

**Keywords:** rural human settlement; Zhejiang Province; evaluation index system; spatiotemporal differentiation



**Citation:** Xu, F.; Zheng, G.; Zhuang, Q. Study on the Spatial-Temporal Characteristics and Divergence of Rural Human Settlement Quality of Mountainous Counties in Zhejiang, China. *Sustainability* **2022**, *14*, 15426. <https://doi.org/10.3390/su142215426>

Academic Editor: Boris A. Portnov

Received: 21 October 2022

Accepted: 14 November 2022

Published: 20 November 2022

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## 1. Introduction

With the development of China's economy, the gap between urban and rural areas has been narrowing, and the disposable income of urban and rural residents in Zhejiang Province from 2016 to 2020 has shown a decline for five consecutive years. Along with economic development, the improvement of the rural human settlement has also become a key element in development work. In 2018, the State Council announced the Three-Year Action Plan for the Improvement of Rural Human Settlement, which gives advice on the improvement of all aspects of work, from the improvement of rural human settlement health to the improvement of village appearance. In promoting the quality improvement of rural

human settlement and rural revitalization, Zhejiang Province has also made corresponding policy improvements in construction, the living environment, and ecological environment protection. From the “ten million project” in 2003 to the beautiful countryside construction template in Anji County in 2009 and then in 2016, the Zhejiang Provincial Party Committee and the provincial government issued the “Action Plan for Deepening the Construction of Beautiful Countryside in Zhejiang Province (2016–2020)”. In 2018, Zhejiang Province issued a political policy on rural human settlement after the State Council. According to the development of rural Zhejiang Province, the “Zhejiang Province to promote a high level of rural human settlement to improve the three-year action plan (2018–2020)” was issued, aiming at “ten million projects” of construction based on the in-depth practice of “green water and green mountains is the silver mountain” development concept, to comprehensively improve and enhance the production, living, and ecological habitat of the countryside [1].

The county is an important administrative unit of governance [2], and the continuous improvement of rural human settlement in Zhejiang Province is closely related to the implementation of corresponding policies by each county according to its current resource characteristics and development (Zhejiang Province 2021–2035 Territorial Spatial Master Plan). Zhejiang Province, on the one hand, has proposed a classification system to promote the development of county characteristics in provincial-level policy. On the other hand, it has proposed various support policies for 26 counties in the province as a demonstration area of common prosperity. The province has put forward various support policies for the 26 counties.

Zhejiang Province, as a demonstration area of common prosperity, has made outstanding achievements in economic development and the urban–rural gap, but 26 counties in mountainous areas are still weak links in its development, both in terms of economic development and rural human settlement enhancement work, and the excellent degree of rural human settlement, as an important carrier of rural residents’ life, is an important indicator of rural residents’ well-being and happiness. Therefore, the objective of this study is to explore the spatial-temporal characteristics of the rural human settlement in the mountainous counties of Zhejiang Province as well their influencing factors based on the evaluation index system that is constructed for quality improvement in these areas. The study of the recent development characteristics of rural human settlement in these counties and the divergent situation plays a guiding role in improving the quality level of the rural habitat, and it plays a role in laying a firm foundation for reaching the goal of common prosperity in Zhejiang Province.

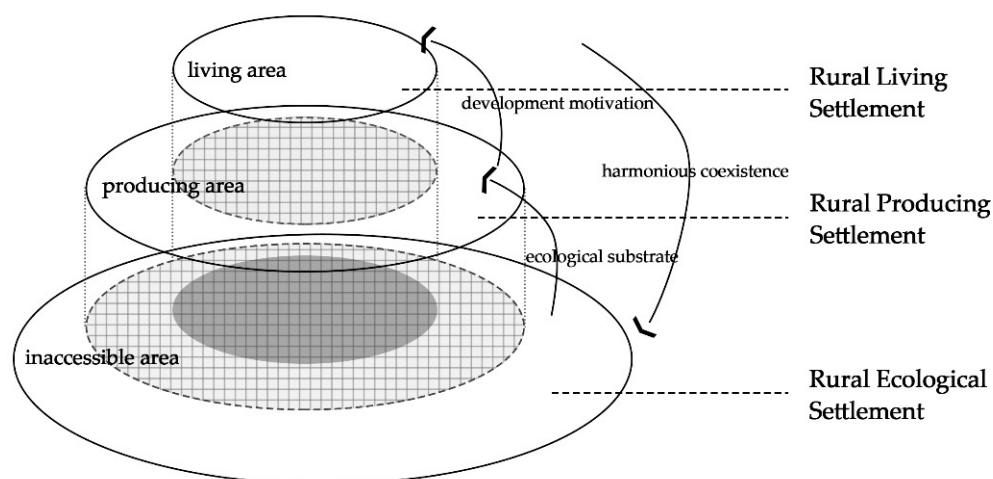
To achieve this research objective, the rest of this paper is organized as follows. The “Literature Overview” introduces the concept of the countryside and the development and research results of rural human settlements in Chinese academia and summarizes the composition of the rural human settlement and the logic of the interplay between internal elements. Meanwhile, the “Methods and Materials” introduces the overview of the research object and the research method, establishes the relevant index system, and gives pre-processing of the data for preliminary processing. The “Results” section introduces the results of the spatial and temporal variation of rural habitat quality in the mountainous counties of Zhejiang Province and the analysis of influencing factors. Finally, the “Discussion and Conclusions” summarizes the main findings of this study and proposes opinions on the future improvement of habitat quality in the mountainous villages of Zhejiang Province based on the results of the study.

## 2. Literature Overview

The concept of the countryside is derived from the formation and development of villages [3]. Tracing its origins to the creation of the countryside, the concept often refers to the settlement of people engaged in agricultural activities, i.e., rural settlements. In the context of the second great division of labor, which led to the separation of agriculture and handicrafts and the emergence of commodity production for exchange purposes,

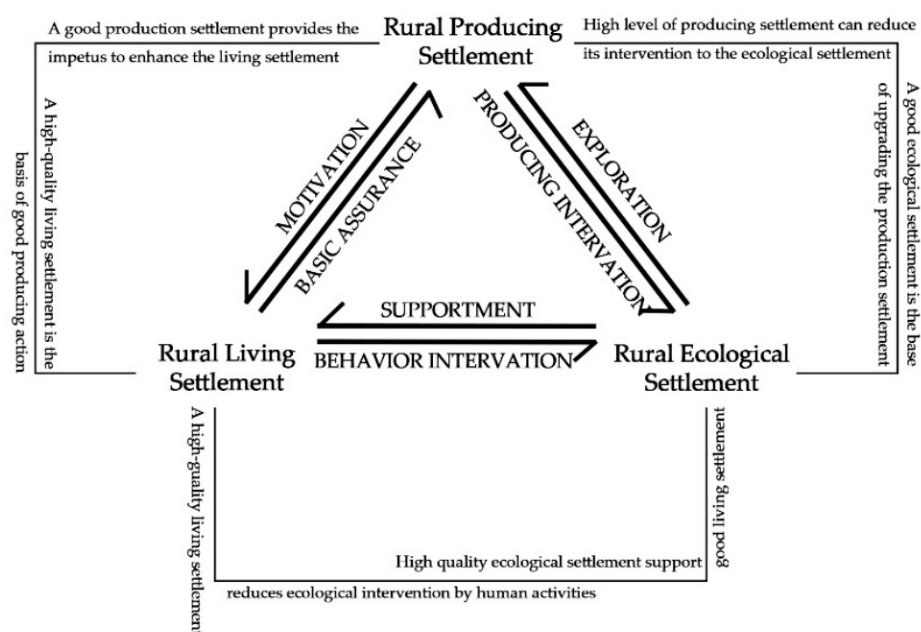
cities gradually emerged, becoming the settlements of people engaged in non-agricultural production activities, and rural human settlements were the living and production spaces of people engaged in agricultural activities [4]. The domestic disciplines that have studied the rural human settlement are mainly geography, architecture, and sociology [5–7], and the interpretation of the meaning of the rural human settlement is roughly divided into two types: from the macroscopic perspective and from the microscopic perspective.

In the study area of the rural human settlement, domestic scholars' research contents and methods are mainly based on the study of the rural human settlement in different scales, so as to come up with corresponding definitions for it. Wu Liangyong proposed that the human settlement is the place in which human beings live together, the surface space closely related to human survival activities, the base on which human beings live in nature, and the main place in which human beings use and transform nature [8]. Scholars in the field of architecture believe that the rural human settlement is "an important element of urban and rural human settlement, consisting of rural social environment, natural environment and artificial environment. It is a comprehensive reflection of the ecological, environmental and social aspects of the countryside" [9]. Scholars in the field of geography believe that the rural habitat is the living environment of rural residents in settlements related to living and basic production activities [10]. Some scholars directly divide the rural habitat into a "hard settlement" and a "soft settlement", as well as a physical settlement and a non-physical settlement [11] (Figure 1).



**Figure 1.** Deconstruction of rural human settlement.

The countryside is the territorial space in which people produce and live. In addition to the settlement aspect, the countryside also contains a vast uninhabited area. When interpreting the rural human settlement from the perspective of settlement space, it can be decomposed into the material and immaterial settlement in the economic production space, the material and immaterial settlement in the daily life space, the material and immaterial settlement in the leisure and recreation space, and the ecological value and economic value of the uninhabited ecological area. The ecological value and economic value of uninhabited ecological areas have an impact on the rural human settlement in all aspects. Therefore, when measuring the quality of the rural human settlement, these three aspects should be measured together, so as to reflect the quality level of each subsystem relatively objectively and judge the settlement's development status and improvement direction according to the real development situation (Figure 2).



**Figure 2.** Rural human settlement subsystem impact logic.

The current rural human settlement evaluation research has made certain achievements, gradually shifting from municipal, provincial, and national rural human settlement evaluation research [12,13] to the exploration, evaluation, and optimization of the spatial and temporal change mechanisms of rural human settlements in areas with different resource endowments, geographical features, and policy characteristics [14–18]. The research results have inheritance as well as local characteristics, and the index system of relevant research is often borrowed from the earlier evaluation index system, while deconstructing the relevant characteristics of the study area, so as to establish a scientific evaluation system to evaluate the study area. Commonly used evaluation methods of human settlements include the questionnaire survey method, the entropy value method, the hierarchical analysis method, the Delphi method, the structural equation modeling method, and the fuzzy comprehensive evaluation method [19]. In the study of the rural human settlement, the entropy method, hierarchical analysis, and the fuzzy comprehensive evaluation method are used most often [20–22].

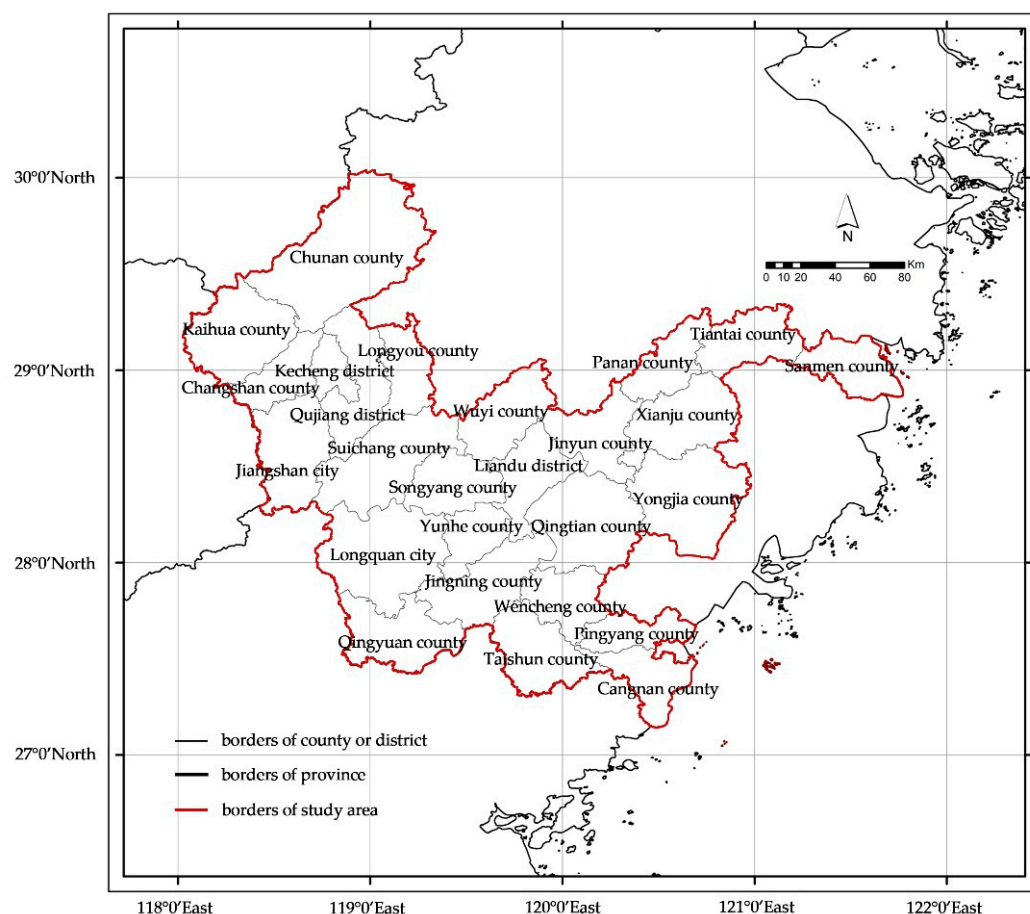
In the analysis of spatial and temporal variations in the rural human settlement, the existing research results are mainly divided into the study of spatial and temporal distribution characteristics and the study of factors affecting spatial and temporal variations. The spatio-temporal distribution characteristics are mainly analyzed by spatial hot and cold spot analysis, spatial trend surface analysis, and mathematical analysis [18,23], whereas the related factors of spatial differentiation are studied by multiple regression, gray correlation, GWR, and geographic probe [24–27].

### 3. Methods and Materials

#### 3.1. Study Area

Mountain counties in Zhejiang Province are located in the southwestern part of Zhejiang Province (Figure 3), a relatively less economically developed region of Zhejiang Province. The area includes 26 mountain counties that have long enjoyed various policy preferences, including Chun'an County in Hangzhou, Pan'an County and Wuyi County in Jinhua City, Tiantai County, Sanmen County and Xianju County in Taizhou City, Yongjia County, Pingyang County, Wencheng County, Taishun County, and Yongjia County in Wenzhou City, the whole area of Lishui City, and the whole area of Quzhou City—a total of 23 counties and three districts, involving six cities, bordering Anhui, Jiangxi, and Fujian. Compared with other counties in the province, the 26 counties are located on the edge

of Hangzhou, the economic growth pole of Zhejiang Province, and Ningbo, the growth center. They are relatively weak in economic development and constitute the weak zone of rural construction in Zhejiang Province. Quzhou, Lishui, Wenzhou, and many other counties are located in mountainous and hilly areas, and the complex terrain causes inconvenient transportation and slow development on the one hand, and on the other hand, it also causes greater resistance to the improvement of rural human settlements in the deep mountainous areas.



**Figure 3.** Location map of mountainous counties in Zhejiang Province.

In 2021, the central government issued a document to encourage support for the current exploration of high-quality development in Zhejiang Province to build a demonstration zone of common endowment, meaning that Zhejiang Province needs to further make up for the shortcomings in development and enhance the economic level of developmentally disadvantaged areas. Relatively, the mountainous counties of Zhejiang Province have long been the focus of various policies in Zhejiang Province to improve the rural human settlement as a carrier of rural residents' producing and living rest, and its improvement has become a key part of the work of the common wealth.

### 3.2. Methods

In measuring the level of the rural human settlement quality in the mountainous counties of Zhejiang Province, it must be considered that the purpose of this study is to analyze their developmental characteristics and to provide development strategies. Furthermore, it is a study that to provide opinions for improving rural human settlement quality at the action level, which is more subjective. The AHP method was chosen during method selection to avoid the use of some objective methods in which the selected factors would be judged to be high because of the size of change in the selected factors. The



importance of these factors was avoided by using some objective methods, so that the factors with low variation but subjective high weights were ignored [28–31].

In analyzing the forces of influencing factors, scholars commonly use research methods such as multiple regression gray correlation and geographic probes. In this study, in order to explore the force of the spatial heterogeneity of the rural human settlement and the interaction and superposition between different factors, the geographic probe was used to analyze the impact factors on the settlement quality in the mountainous counties of Zhejiang Province. The geographic detector is a spatial heterogeneity analysis tool, which consists of four detectors: the factor detector, the risk area detector, the ecological detector, and the interaction detector. Its theoretical basis is based on spatial autocorrelation, and the core idea is based on the assumption that if an independent variable has an important influence on a dependent variable, then the spatial distribution of the independent variable and the dependent variable should have a similarity. Because it avoids the condition of linearity assumption, the geographic detector can more objectively reflect the extent to which the independent variable explains the spatial variation of the dependent variable, so it is widely used in economic evaluation, urbanization, physical geography, medical care, and many other fields.

### 3.2.1. Establishment of the Evaluation Index System and Impact Factor Analysis System

#### (1) Establishing an evaluation index system

When establishing an evaluation system for the rural human settlement quality for the 26 counties in mountainous areas of Zhejiang Province, in order to make the system truly reflect the level of rural human settlement quality, it should be adapted to local conditions, taking into account the existing level of rural human settlement development in Zhejiang Province, on the one hand, and local factors such as the socio-economic level, topographic features, and future development goals of mountainous counties, on the other hand. These factors should be combined with an existing rural human settlement evaluation index system, and an index system should be developed that is in line with the current situation and the characteristics of the target.

As illustrated in the literature review, the rural human settlement can be structured into three sub-settlements from the perspective of spatial settlement, namely, the rural production settlement, the rural living settlement, and the rural ecological settlement. Thus, the system layer was divided based on these three parts. The indicator layer is a subdivision of the meaning of the upper system layer, and its selection is based on the meaning of the indicators in the system layer on the one hand, and on the other hand, it sorts out and integrates the indicators that appear in the existing rural human settlement evaluation index system according to their frequency. The index layer is a further subdivision of the indicator layer, which can be measured by numbers of indicators that can be depicted with precise data (Appendix A). The indicators in the indicator layer are those that describe a certain performance aspect of the production, life, and ecological settlement, which are more specific than the indicators in the system layer and broader than the indicators in the index layer (Table 1). Using the AHP method, the consultants selected a total of 20 people, including urban and rural planning and tourism experts and professors, planning and rural practitioners from government departments, senior practitioners from planning and design institutes, doctoral and master's students from urban and rural planning and tourism planning and geography universities, people living in local rural areas in the 26 mountainous counties, etc. Finally, 15 valid questionnaires were obtained (Appendix B). The weights of each index at all levels calculated by the hierarchical analysis method were derived from the judgments made by various experts based on their personal knowledge and working experience of the importance of each index in the comprehensive evaluation of the rural human settlement. Yaahp software was used to calculate and finally determine the weights of each index system for evaluating the rural human settlement in the 26 counties in the mountainous areas of Zhejiang Province.

**Table 1.** Evaluation index system and weight of rural human settlement quality in 26 mountainous counties of Zhejiang Province.

| Objective Level                                                                                   | System Layer                     | Indicator Layer              | Index Layer                                        | Characteristics of Indicators | Comprehensive Weight |
|---------------------------------------------------------------------------------------------------|----------------------------------|------------------------------|----------------------------------------------------|-------------------------------|----------------------|
| Settlement quality of rural villages in 26 counties in mountainous areas of Zhejiang Province (A) | Rural Production Settlement      | Economy Development (C1)     | Economy level (D1)                                 | +                             | 0.0611               |
|                                                                                                   |                                  | Agriculture Development (C2) | Level of agricultural development (D2)             | +                             | 0.0843               |
|                                                                                                   |                                  |                              | Degree of modernization in agriculture (D3)        | +                             | 0.0367               |
|                                                                                                   |                                  | Rural Employment (C3)        | Residents' employment situation (D4)               | +                             | 0.0712               |
|                                                                                                   | Rural Living Settlement (B2)     | Economy Life (C4)            | Residents' income situation (D5)                   | +                             | 0.0321               |
|                                                                                                   |                                  |                              | Residents' living consumption (D6)                 | +                             | 0.013                |
|                                                                                                   |                                  |                              | Livelihood assurance for residents (D7)            | +                             | 0.0414               |
|                                                                                                   |                                  |                              | Electricity consumption level (D8)                 | +                             | 0.0512               |
|                                                                                                   |                                  | Infrastructure (C5)          | Highway construction level (D9)                    | +                             | 0.065                |
|                                                                                                   |                                  |                              | Construction level of convenient facilities (D10)  | +                             | 0.0695               |
|                                                                                                   |                                  |                              | Sanitary toilet penetration (D11)                  | +                             | 0.0606               |
|                                                                                                   |                                  | Healthcare (C6)              | Construction of primary medical institutions (D12) | +                             | 0.0286               |
|                                                                                                   |                                  |                              | Level of primary care services (D13)               | +                             | 0.035                |
|                                                                                                   |                                  |                              | Beautiful countryside construction (D14)           | +                             | 0.0583               |
|                                                                                                   |                                  | Built-up Area Quality (C7)   | Scenic area construction (D15)                     | +                             | 0.0181               |
|                                                                                                   |                                  |                              | Primary and secondary education level (D16)        | +                             | 0.0512               |
|                                                                                                   |                                  | Culture and Education (C8)   | Cultural infrastructure construction (D17)         | +                             | 0.0159               |
|                                                                                                   |                                  |                              | Intensity of pesticide use in agriculture (D18)    | +                             | 0.0803               |
|                                                                                                   | Rural Ecological Settlement (B3) | Environmental pollution (C9) | Intensity of fertilizer use in agriculture (D19)   | +                             | 0.0328               |
|                                                                                                   |                                  |                              | Sewage treatment situation (D20)                   | +                             | 0.0494               |
|                                                                                                   |                                  | Natural Condition (C11)      | Air quality (D21)                                  | +                             | 0.018                |
|                                                                                                   |                                  |                              | Level of forest cover (D22)                        | +                             | 0.0194               |

## (2) Establishing an impact factor analysis system

The quality of rural human settlement is influenced by various factors such as natural, social, and economic factors. On the one hand, good rural industrial development, rural human settlement optimization, and improvement of the ecological environment can effectively improve the quality of the rural human settlement. On the other hand, the economic base, existing construction base, and natural resource endowment of each county also have an impact on the quality of the rural human settlement to a certain extent. The mountainous counties in Zhejiang Province have different geographical characteristics and developmental backgrounds from other regions, so analyzing the factors and mechanisms

affecting rural human settlement according to local conditions can provide a more scientific and targeted improvement strategy for the current study area.

When selecting the impact factors, a distinction should be made between the indicators in the evaluation index system and the impact factor indicators. The factors in the evaluation index system are all factors that directly affect the dimensions of rural human settlement, whereas the impact mechanisms of rural human settlement quality should be selected from the study unit and linked to the evaluation index system dimensions but focus on the overall characteristics of the study unit, so as to examine the impact of economic, social, and geographical factors on rural human settlement in the larger environment.

The factors affecting the quality of the rural habitat in the 26 counties and the analysis of their influencing mechanisms should be based on existing research results, while taking into account the geographical characteristics and development status of these counties. This paper analyzes the influence mechanisms of factors affecting rural human settlement in the 26 counties by selecting three dimensions, including economic development, social infrastructure, and natural conditions and resource endowment (Table 2).

**Table 2.** Human settlement impact factor system of rural villages in mountainous counties of Zhejiang Province.

| System Layer                                          | Indicator Layer              | Detection Factor                           |
|-------------------------------------------------------|------------------------------|--------------------------------------------|
| Economy                                               | Economic development level   | GDP per capita                             |
|                                                       | Industry structure           | Second and third industries accounted for  |
| Urban and rural development and social infrastructure | Local financial level        | Fiscal revenue per capita                  |
|                                                       | Agricultural modernization   | Agricultural machinery power per capita    |
|                                                       | Urban development facilities | Urbanization rate                          |
| Natural conditions and resource endowment             |                              | Traffic Density                            |
|                                                       | Arable land resources        | Crop sown area per capita                  |
|                                                       | Tourism resources            | Number of 3A-class scenic spots            |
|                                                       | Terrain characteristics      | Average elevation of core residential area |
|                                                       | Topography characteristics   | Mountain coverage area                     |

### 3.2.2. Data Collection and Processing

In this study, based on the research results of the existing rural human settlement evaluation index system, the provincial-, municipal-, and county-level rural human settlement-related policies of Zhejiang Province were sorted out, and the quantifiable keywords related to these policies were extracted and frequency statistics were conducted, before finally improving the rural human settlement quality evaluation index system in the mountainous counties of Zhejiang Province. By evaluating the quality of rural human settlement in these counties from 2016 to 2020, we analyze the current development characteristics, development trends, and influencing factors of the rural human settlement in the Zhejiang Province and the mountainous counties of Zhejiang Province, and provide guidance for its further improvement.

In choosing the study interval, considering that the study is meant to provide a foundation for rural construction for the further development of the 10 million project and the construction of the demonstration area of the commonwealth, the data of five years from 2016 to 2020 were chosen, so that the development characteristics of the current stage as well as the development trends can be clearly reflected, thus providing the basis for the establishment of the recent work. The data for the study were obtained from the 2016–2020 Statistical Yearbook of the cities belonging to 26 counties in Zhejiang Province, the 2016–2020 statistical bulletin of each of the 26 counties, the data-sharing platform of Zhejiang, the bulletin of the National Tourism Administration, the bulletin of the Zhejiang Provincial Tourism Administration, the bulletin of each county tourism bureau, the “Thousand Villages Demonstration and Ten Thousand Villages Improvement” bulletin in the



past years, and the data collected through Pathyon's Office bulletin, as well as information obtained by means of Pathyon.

After searching and integrating the data of the 26 counties in Zhejiang Province from 2016 to 2020, a total of 2990 pieces of data were counted, and 2860 pieces of data were processed for data type consistency and normalization before calculating the weighted scores in order to eliminate the influence of units and the nature of indicators and to solve the problem of incommensurability before each indicator.

Since the indicators of the index system produced by the AHP method in this study have both positive and negative effects on the final results, it is necessary to make the data type consistent before applying it to a weighted calculation. In the study of the spatiotemporal evaluation and optimization of the human settlement of the 26 villages, the negative indicators were processed by the inverse method with the following formula:

$$X_{ij} = \frac{Max - x_{ij}}{Max - Min} \quad (1)$$

In this equation,  $X_{ij}$  is the processed data,  $x_{ij}$  is the collected data,  $Max$  is the maximum value among the processed data of the same type, and  $Min$  is the minimum value among the processed data of the same type.

Interventionary studies involving animals or humans and other studies that require ethical approval must list the authority that provides approval and the corresponding ethical approval code.

After the index system is determined, due to the existence of different units in the collected data, and in order to minimize the impact of the incommensurability between different nature indicators on the final results when calculating the scores, dimensionless processing of the collected indicators is necessary, and in this paper, the processing method of normalization in linear dimensionless processing is used for each indicator. The specific formula is:

$$X_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j} \quad (2)$$

In this equation,  $X_{ij}$  is the processed data,  $x_{ij}$  is the collected data,  $\bar{x}_j$  is the tie value of this data for that year, and  $S_j$  is the standard deviation.

The indicator weights are calculated from Yaahp and weighted by combining the indicator weights with the data after type consistency as well as dimensionless normalization. Considering the existence of 0 values after normalization, 0.1 was added to all the data after the dimensionless calculation and before the weighting calculation, and the evaluation scores of the rural human settlement of each county for each year were obtained.

## 4. Results

### 4.1. Analysis of Spatial and Temporal Distribution of Rural Habitat Quality in Mountainous Counties of Zhejiang Province

#### 4.1.1. Spatial and Temporal Evolution Characteristics of Rural Human Settlement in Mountainous Counties of Zhejiang Province

The processed data were weighted to obtain the five-year score of the data of rural human settlement in the mountainous counties of Zhejiang Province. Through preliminary analysis of the data, it could be found that the overall rural human settlement in the 26 counties displayed an upward trend, among which Changshan County (10.12%), Yunhe County (9.44%), and Cangnan County (9.36%) showed a high rate of improvement, whereas Liandu District, Kaihua County, and Chun'an County were relatively weak in development. Through the mathematical analysis of the scores of each county over the years, it could be found that the standard deviation is increasing, and the coefficient of variation is decreasing, which shows that the dispersion of the distribution of rural human settlement quality among the counties is increasing, and the rural human settlement of the 26 is a development trend of simultaneous improvement, but the gap is increasing (Table 3).

**Table 3.** Mathematical and statistical analysis of rural habitat scores in 26 counties in mountainous areas.

| Year | Average Score | Standard Deviation | Variable Values |
|------|---------------|--------------------|-----------------|
| 2016 | 0.408         | 0.037              | 0.092           |
| 2017 | 0.456         | 0.041              | 0.090           |
| 2018 | 0.514         | 0.047              | 0.091           |
| 2019 | 0.569         | 0.048              | 0.084           |
| 2020 | 0.598         | 0.051              | 0.085           |

For the analysis of spatial correlation characteristics, the Moran index analysis method was used to analyze the average degree of correlation between each spatial unit and the surrounding space in the 26 counties from 2016 to 2020, using the data source of the comprehensive evaluation scores of human settlement in each year in the 26 counties. Considering that the existence of adjacent interface contact length between spatial units of each county and adjacent county units will affect the calculation of the degree of influence on the human settlements between the units, the CONTIGUITY-EDGES-CORNERS calculation method was used in the calculation of Moran's index estimates for this spatial autocorrelation analysis, and the evaluation of rural human settlement from 2016–2020 was derived using Moran's I estimates of the results (Table 4).

**Table 4.** Moran's I estimated value of rural human settlement evaluation results of 26 counties in mountainous area of Zhejiang Province.

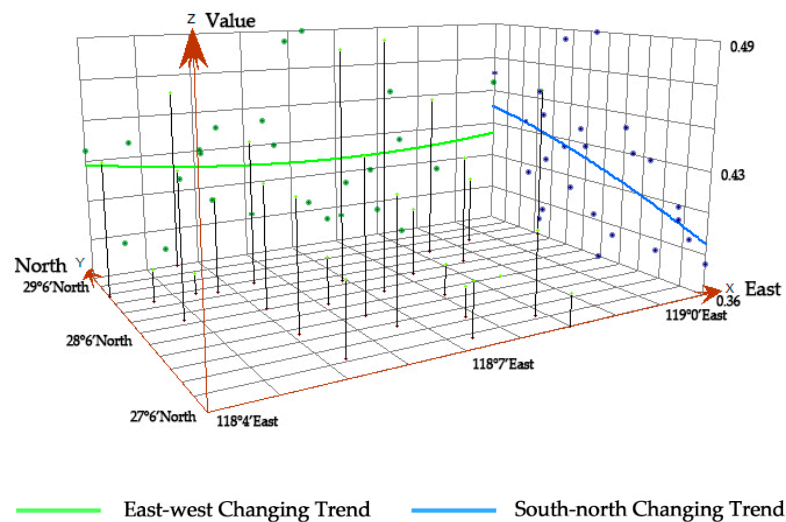
| Year | Moran's I | Variance | Z-Score | p-Value |
|------|-----------|----------|---------|---------|
| 2016 | 0.0585    | 0.0189   | 0.7169  | 0.4734  |
| 2017 | 0.0436    | 0.0191   | 0.6052  | 0.5451  |
| 2018 | 0.1179    | 0.0183   | 1.1662  | 0.2435  |
| 2019 | 0.0690    | 0.0181   | 0.8095  | 0.4182  |
| 2020 | 0.0409    | 0.0185   | 0.5957  | 0.5514  |

According to the analysis principle of Moran's I index, the obtained data were checked for the z-score and *p*-value, and it was found that the scores for 2016–2020 failed the significance test (Appendix C). This indicates that there is no spatial agglomeration characteristic of the rural human settlement in the 26 counties. For a long time, Zhejiang Province has been implementing categorical development policies and one-county-one-policy policies based on its block economic development characteristics and hilly terrain factors, making the development of rural human settlement quality independent of each other among counties. Therefore, when formulating relevant optimization policies, relevant optimization and improvement opinions should be proposed from the development types of rural human settlement in each county.

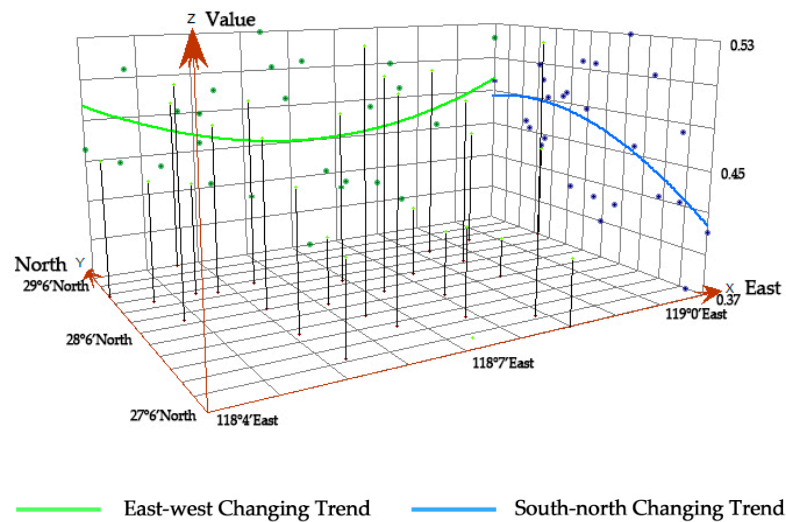
In analyzing the spatial distribution trend characteristics of rural habitat quality levels over a five-year period, the trend surface analysis method was used for visualization. Trend surface analysis is a tool for spatial analysis in ArcGIS, which can analyze the spatial trend characteristics of each point or surface according to the spatial distribution of sample data. In the spatial and temporal analysis of habitat quality in the mountainous areas of Zhejiang Province, in order to reflect the evolution of spatial characteristics, the trend surface analysis tool in ArcGIS was used to further analyze the evaluation scores over a five-year period. The spatial distribution pattern and change trend were visualized in three dimensions, resulting in the following Figure 4, in which the blue line indicates the trend of the north-south direction, and the green line indicates the trend change in the east-west direction.

The analysis of the spatial trends of the evaluation scores from 2016 to 2020 shows that, in the north-south direction, the quality of rural human settlement in the north is higher than that in the south, but the trend line segment on the z-axis is constantly rising,

which indicates that the overall quality of human settlement is rising simultaneously. In the east-west direction, it can be found that the trend line segment gradually changes from a smooth “one” shape to a positive “U” shape, and the eastern part is significantly higher than the western part. This indicates that the development speed of rural human settlement in the central region is relatively low and shows an obvious gap, whereas the development of rural human settlement quality in the east is the best, but the overall trend line is still upwards, indicating that the overall quality is on the rise.

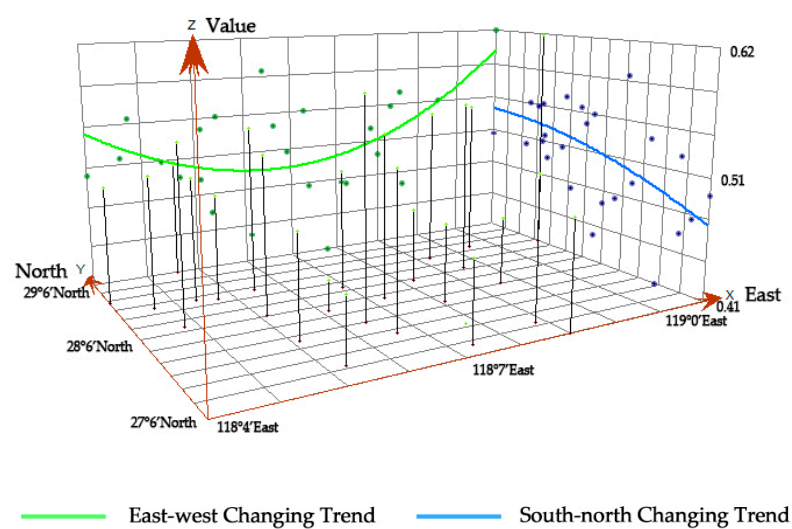


(a) 2016

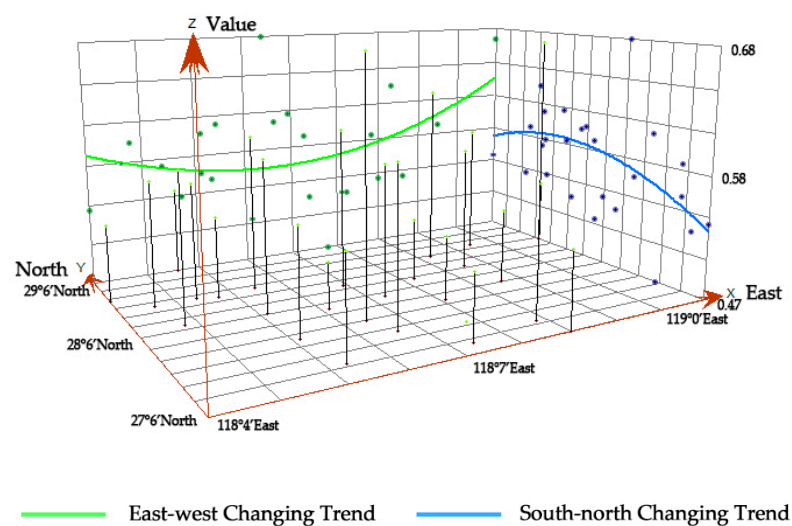


(b) 2017

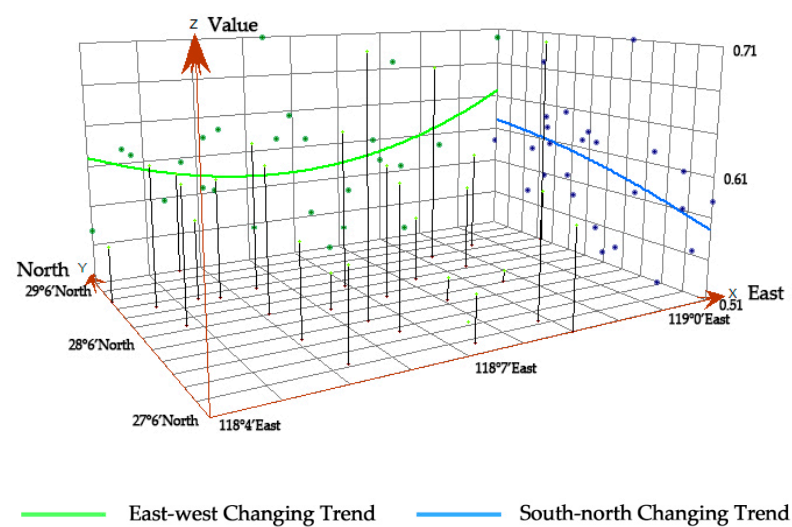
Figure 4. Cont.



(c) 2018



(d) 2019

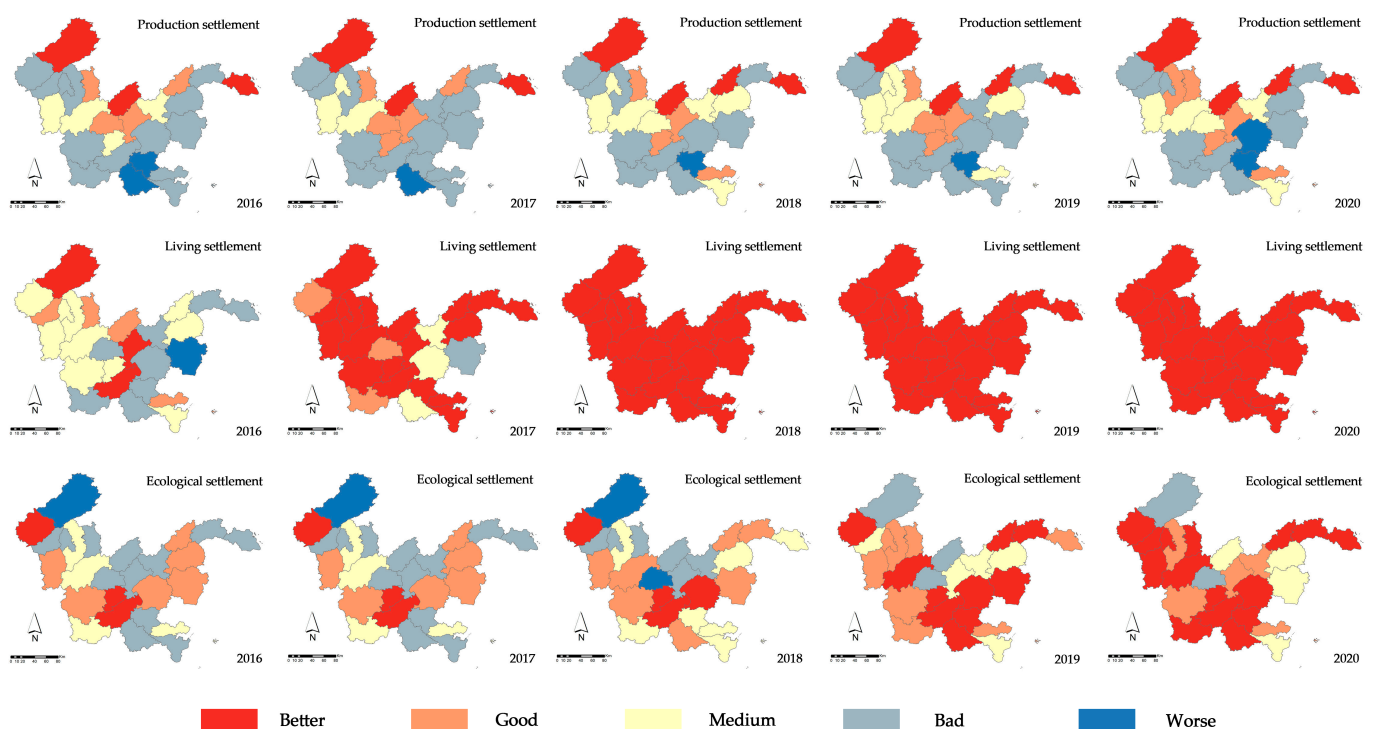


(e) 2020

**Figure 4.** The spatial trend of rural residential environment quality in 26 counties in mountainous areas from 2016 to 2020 (a–e).

#### 4.1.2. Evolutionary Characteristics of Rural Human Settlement Subsystems in Mountainous Counties of Zhejiang Province

In this study, in order to deeply explore the spatial and temporal variation characteristics of the rural human settlement in the mountainous areas of Zhejiang Province from 2016 to 2020 and to explore the potential causes affecting development of rural human settlement quality in 26 counties in mountainous areas in Zhejiang Province, the performance of the counties in the criterion layer is also analyzed, because the rural human settlement underlying this evaluation is composed of the rural human production settlement, the rural human living settlement, and the rural human ecological settlement, so the quasi-measurement layer in the three dimensions are considered to be subsystems of the rural human settlement system. According to the evaluation results of the counties, the lowest year of each subsystem's human settlement level is used as the basis for classification, and the rural human settlement level of each subsystem is classified into five levels: high, high, average, low, and low, to make a spatial and temporal distribution map of rural human settlement. Comparing the five-year spatio-temporal changes, the spatio-temporal distribution characteristics of each subsystem can be found, and the reasons for their distribution and development can be inferred according to the development base as well as the development characteristics of each county (Figure 5).



**Figure 5.** Spatial trend of the quality level of rural human settlement subsystems in 26 counties in mountainous areas from 2016 to 2020.

(1) The overall trend of rural habitat production environment in the mountainous counties of Zhejiang Province is on the rise, and some counties with lower quality have all reached a relatively good state of rural habitat production environment after five years of development, especially Taishun County (13.37%), Cangnan County (9.72%), and Pingyang County (9.02%). Considering the impact of the epidemic, however, some counties have also experienced a certain decline, and the data anomalies are shown in the annual data from 2020, such as in Wencheng County (−2.16%) and Qingtian County (−3.07%). In terms of the temporal pattern, the coefficient of variation shows no significant change, which indicates that the dispersion of rural human production settlement quality in the 26 counties in mountainous areas is small in five years, and the gap between counties

has changed less. In terms of the spatial pattern, the northern area always maintains a high quality of rural habitat production environment, and the higher-ranked Sanmen County, Wuyi County, and Chun'an County are located in the northern part. Meanwhile, the quality of the northern habitat production environment shows a decline in the data due to the epidemic and the economic downfall of the tourism-oriented counties in the north in 2020, such as Tiantai County, Xianju County, Qingtian County, etc., which shows that the epidemic has also created an impact on the economic production activities of rural residents. The reason why the rural human production settlement shows the spatial characteristics of good development in the north but relatively balanced distribution at the same time, on the one hand, is the radiation influence brought by the strong economic development in the north, including Hangzhou metropolitan area and Ningbo metropolitan area. On the other hand, the block economic development characteristics of Zhejiang Province and local support policies also make the north-south development relatively balanced, and the quality of rural human production settlement does not show polarized development, a siphon effect, or another unhealthy state, except for individual counties such as Qingtian County, which is developing slowly and at a lower level due to certain resistance in terms of resources, topography, location, and other factors.

(2) The overall improvement of the rural human living settlement in the mountainous counties of Zhejiang Province has been fast. The graph surface presentation shows that the overall trend has improved to a good level of quality from 2016 to 2018. The fastest improvements include Yunhe County (15.46%), Yongjia County (15.35%), and Sanmen County (13.75%), whereas relatively slow development is taking place in Chun'an County, Liandu District, and Jingning. In terms of the temporal pattern, the coefficient of variation from 2016 to 2020 shows a decreasing trend, indicating that the difference in the quality of the rural human living settlement among counties is narrowing, but in terms of the value, the magnitude of the reduction keeps decreasing. In the performance score of each county, it can be found that most counties exist in a state with a high score and a high variation rate, which to a certain extent reflects the fact that the quality of the settlement in each county has strongly improved in the past five years. The reason for this is related to the long-term deepening of the construction rules of the thousand villages project and the development of rural infrastructure construction in Zhejiang Province. Yunhe and Sanmen counties show a high score and a high change rate status, which indicates that these two counties have greater research and exploration significance in development strategies. In terms of the spatial pattern, the rural human living settlement of the 26 counties in mountainous areas showed a five-year shift from an obvious advantage in the north to a good overall performance to a narrowing of differences among counties and excellent point performance, mainly in Changshan in the eastern region, Yunhe County in the central region, and Xianju County and Sanmen County in the western region.

(3) The overall rural human ecological settlement shows a slow upward trend, among which the fastest rising areas include Changshan County (11.06%), Kecheng District (9.2%), and Sanmen County (7.35%). Among the counties with relatively slow development, Yongjia County, Xianju County, and Liandu District have lower scores. In terms of time pattern, the coefficient of variation of the score of each county gradually decreases and the gap gradually decreases, showing a change in the overall score trend from a smaller growth rate to a larger growth rate and then to a smaller growth rate. In terms of the spatial pattern, the rural human ecological settlement of the 26 counties in the mountainous region has always shown the distribution characteristics of a better performance in the southern counties in the development process. This indicates that the two mountain policy concept has been implemented to a certain extent, and strong industrial counties focus on the maintenance and improvement of the rural human ecological settlement while also focusing on economic development, realizing a situation of economic and ecological excellence. Meanwhile, the counties with a better ecological base show a smaller increase, and their already good ecological base as well as the development strategies of Lishui and Quzhou to implement ecological industries are the main reasons for this development.



#### 4.2. Analysis of Influencing Factors

Based on the results of the influence factor system in the Methods section, this study took the data of 2020 as the research object. We measured the degree of influence of each factor in the system of influencing factors on the quality of rural human settlement in each county of the mountainous region of Zhejiang Province in that year, and the magnitude of is reflected by the Q value (Table 5).

**Table 5.** Detection results of environmental quality impact factors of rural human settlement in 26 mountainous counties of Zhejiang Province.

| System Layer                                          | Indicator Layer              | Detection Factor                              | Q     |
|-------------------------------------------------------|------------------------------|-----------------------------------------------|-------|
| Economy                                               | Economic development level   | GDP per capita                                | 0.384 |
|                                                       | Industry structure           | The second and third industries accounted for | 0.279 |
|                                                       | Local financial level        | Fiscal revenue per capita                     | 0.355 |
| Urban and rural development and social infrastructure | Agricultural modernization   | Agricultural machinery power per capita       | 0.466 |
|                                                       | Urban development facilities | Urbanization rate                             | 0.143 |
|                                                       |                              | Density of the road network                   | 0.107 |
| Natural conditions and resource endowment             | Arable land resources        | Crop sown area per capita                     | 0.236 |
|                                                       | Tourism resources            | Number of 3A-class scenic spots               | 0.315 |
|                                                       | Terrain characteristics      | Average elevation of core residential area    | 0.243 |
|                                                       | Topography characteristics   | Mountain coverage area                        | 0.309 |

From the detection results, the selected 10 factors all have a certain influence on the quality of rural human settlement, but there are large differences in the degree of influence, among which the level of agricultural modernization (X4), the level of economic development (X1), and the level of local finance (X3) are more influential, and tourism resources (X8), topographic features (X10), industrial structure (X2), and topographic features (X9) have relatively less influence. Meanwhile, arable land resources (X7), the urbanization rate (X5), and the density of the road network (X6) have a lower influence.

In terms of impact dimensions, the economic development dimension has the greatest impact on the quality of rural human settlement, and it can be seen that good economic development is the primary factor influencing the improvement of the quality of rural human settlement. Kecheng District (RMB 106,142), Wuyi County (RMB 78,601), and Chun'an County (RMB 73,026), which have a high per capita GDP, have relatively high levels of rural human settlement. This is followed by natural conditions and resources. For example, Jingning She Autonomous Region (91.7%), which has a very high mountain coverage rate, and Taishun County (550 m), which has the highest core residential area poster, still have relatively poor rural human settlement quality despite their relatively good social infrastructure base. The urban-rural development and social infrastructure construction dimensions have a weaker influence on rural human settlement, which shows that although good social infrastructure construction and good urbanization levels theoretically have a greater influence on rural human settlement, considering that the development characteristics of the Zhejiang villages have a good infrastructure construction status, this dimension shows a weaker influence on rural human settlement in the empirical results. However, considering that the development characteristics of Zhejiang's rural areas have been in a good state of infrastructure construction, this dimension has shown a weaker influence on the quality of rural human settlement.

The interaction between the factors can uncover the category of this interaction, and in this study, the mode of action can be mainly classified as two-factor enhancement or non-linear enhancement, according to the explanatory power of the interaction between the two factors. The two-factor enhancement represents a strong interaction between the two factors, whereas the non-linear enhancement indicates that the combination of the two factors has less influence on the dependent variable.

After analyzing the interaction results of the ten factors, it was found that most of the three dimensions and ten factors selected showed non-linearly enhanced explanatory power (Figure 6), i.e., each factor had a certain influence on the quality of rural human settlement but did not have a strong interaction at the same time. However, five groups of factors also produced a two-factor enhancement, including the level of economic development (X1) and tourism resources (X8), the level of economic development (X1) and topographic features (X10), the level of local finance (X3) and the level of agricultural modernization (X4), the level of agricultural modernization (X4) and arable land resources (X7), and the level of agricultural modernization (X4) and tourism resources (X8). The combination of these five sets of influencing factors possessing a two-factor enhancement effect indicates that among the factors that have an impact on the quality of rural human settlement, these five sets of factors produce a utility of  $1 + 1 > 2$ . When improving the quality of rural human settlement at the county level, a greater utility will be produced from these five sets of influencing factors.

|     | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 |
|-----|----|----|----|----|----|----|----|----|----|-----|
| X1  |    |    |    |    |    |    |    |    |    |     |
| X2  |    |    |    |    |    |    |    |    |    |     |
| X3  |    |    |    |    |    |    |    |    |    |     |
| X4  |    |    |    |    |    |    |    |    |    |     |
| X5  |    |    |    |    |    |    |    |    |    |     |
| X6  |    |    |    |    |    |    |    |    |    |     |
| X7  |    |    |    |    |    |    |    |    |    |     |
| X8  |    |    |    |    |    |    |    |    |    |     |
| X9  |    |    |    |    |    |    |    |    |    |     |
| X10 |    |    |    |    |    |    |    |    |    |     |

**Figure 6.** Interactive detection results of impact factors on rural human settlements in Zhejiang province.

## 5. Discussion and Conclusions

The results of this research present several key features. First, compared with the existing classical rural human settlement quality evaluation results [13,21], the evaluation system of rural human settlement quality in the mountainous counties of Zhejiang Province in this study was obtained by integrating the existing results with the development characteristics and policy features of the counties. The evaluation index system in this study has the characteristics of timeliness and locality. Second, unlike the evaluation results of rural human settlement quality in other regions, the results of this study area do not have spatial clustering characteristics [25,32], which is in line with the characteristics of the study area's research units having relatively independent development policies and inconvenient connections caused by mountainous areas. Finally, at the same time, the quality of the rural living settlement, as shown by its spatial and temporal variation in quality, has improved the fastest, and the gap has become smaller, similar to the results of rural human settlement quality studies in other inland regions of China [24,25,32], which is mainly due to the current Chinese rural habitat policy focusing on living settlement improvement.

The rural human settlement is a carrier of rural residents' producing and living life, and its quality level is an important basis for measuring the degree of rural development. In this study, based on the deconstruction of rural human settlement, a rural human settlement quality evaluation index system based on the policy development characteristics and regional development status of the 26 counties and their rural human settlement quality from 2016 to 2020 was evaluated. From the distribution characteristics, the rural human settlement in the mountainous counties of Zhejiang Province has steadily improved. The overall state of the north is better than the south, and the east and west is better than the central area. In each subsystem, the quality of the producing settlement is higher in the north and lower in the south, the quality of the living settlement is better in the northwest than in the southeast, and the quality of the ecological settlement is lower in the north and higher in the south. Here, the quality of the rural living settlement shows the characteristics of a high score and a high change rate compared with other

subsystems. From the perspective of development trends, the quality of the rural human settlement shows the general characteristics of overall improvement in the central and southern regions, and the subsystem shows the characteristics of slow development of the rural producing settlement. Still, fast development of the rural living settlement, great development potential, and relatively stable improvement of the rural ecological settlement are shown. In the next rural upgrading work, the overall development should pay attention to the south-central counties for targeted assistance and upgrading. In the improvement of the rural producing settlement, the overall situation displays a gentle rise, but the edge of the metropolitan area and areas not covered by the economic circle show more obvious economic weakness characteristics. In view of the economic development factors having the greatest effect on the enhancement of the rural human settlement, the relevant departments should focus on the weak counties on the edges of the metropolitan area to explore the rural industrial potential, shape the characteristic industries, and create core competitiveness while actively integrating these spaces into the metropolitan area. In the improvement of the rural living settlement, the current rapid improvement trend should be maintained, and the “Ten Million Project” should continue to be implemented in order to explore management policies, implementation methods, and development directions for the improvement of the rural habitat and living environment. In the improvement of the rural ecological settlement, given that the 26 counties have a good mountainous ecological environmental foundation, and they have shown a certain trend of improvement, the current ecological base should be mapped. This would ensure the current ecological settlement level and, at the same time, reduce the negative impact of rural producing activities and living activities, in order to ensure that the rural human settlement in the countryside development has a good rural ecological human settlement and to implement the concept of “green water and green mountain is the silver mountain of the mountain”.

The main contribution of this study is divided into two aspects. On the one hand, on the basis of deconstructing the concept of the rural human settlement, this study establishes an evaluation index system of rural human settlement in the mountainous counties of Zhejiang Province with the characteristics of the study area, which fills the gap of the study on the evaluation index system of rural human settlement in the mountainous counties of Zhejiang Province. On the other hand, this study shows the results of the spatial and temporal variation of rural human settlement quality in recent years and analyzes the influence degree of various influencing factors using geographic detectors, which provides a scientific basis for the improvement of the rural human settlement in the mountainous counties of Zhejiang Province.

**Author Contributions:** Conceptualization, F.X., G.Z. and Q.Z.; Data collection, F.X. and G.Z.; Data analysis, F.X. and Q.Z.; Writing—original draft, F.X. and Q.Z.; Writing—review and editing, F.X., G.Z. and Q.Z. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the National Social Science Fund of China, grant number 19BSH109.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author. The data are not publicly available due to the privacy restrictions.

**Acknowledgments:** We would like to thank the anonymous reviewers for their constructive comments and feedback to improve this manuscript.

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

## Appendix A

**Table A1.** The explanation and calculation methods of indicators in the index layer.

| Name of the Indicator                              | Meaning of Indicators                                                                                                                                                                                     | Calculation Method                                                                                                                                              |
|----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Economy level (D1)                                 | Shows the overall level of economic development of the study area.                                                                                                                                        | Gross economic product/total population                                                                                                                         |
| Level of agricultural development (D2)             | The degree of development of the agricultural industry, which is the foundation of the village, can be visually demonstrated.                                                                             | Agricultural output/rural population                                                                                                                            |
| Degree of modernization in agriculture (D3)        | Shows the agricultural capacity of the region.                                                                                                                                                            | Agricultural machinery power/rural population                                                                                                                   |
| Residents' employment situation (D4)               | Shows the employment status of the area under study.                                                                                                                                                      | Number of rural employees/rural population*100%                                                                                                                 |
| Residents' income Situation (D5)                   | Visualizes the current income level of rural residents, and a good income level is the basis to guarantee living standards of rural residents.                                                            | (Total household income–income tax paid–social security expenditure paid by individuals–bookkeeping allowance)/household size                                   |
| Residents' living consumption (D6)                 | Visually expresses the current consumption level of the study area and is an important indicator of the current living conditions of rural residents in the area.                                         | (Annual income of the household–corporate income tax paid–social security expenses paid by individuals–bookkeeping allowance)/number of people in the household |
| Livelihood assurance for residents (D7)            | Expresses the living conditions of low-income groups in the study area.                                                                                                                                   | Government Gazette for each year in each county                                                                                                                 |
| Electricity consumption level (D8)                 | Shows the level of construction of power infrastructure.                                                                                                                                                  | Total electricity consumption in villages/number of people in villages                                                                                          |
| Highway construction level (D9)                    | Shows the current level of road construction in the study area and the convenience for rural residents to go out for production, living, and recreation.                                                  | Road mileage/Number of rural population                                                                                                                         |
| Construction level of convenient facilities (D10)  | The study of the degree of construction of express points has a certain convenience, which is related to the convenience of life of the residents and their convenience in carrying out other activities. | Number of courier points/total number of villages                                                                                                               |
| Sanitary toilet penetration (D11)                  | Visually reflects the current construction of sanitary toilets and is a basic measurement element to ensure the sanitary life of rural residents.                                                         | Number of farm households using sanitary toilets/total number of households in the village                                                                      |
| Construction of primary medical institutions (D12) | Shows the current level of health construction in the study area.                                                                                                                                         | Total number of primary health care institutions/villages                                                                                                       |
| Level of primary care services (D13)               | Shows the current level of health services in the study area.                                                                                                                                             | Number of health technicians/village population                                                                                                                 |
| Beautiful Countryside Construction (D14)           | Visually shows the current level of rural environment construction in the study area.                                                                                                                     | Number of beautiful villages/total number of villages*100%                                                                                                      |
| Scenic Area Construction (D15)                     | Reflects to some extent the current level of the built-up area of construction in the study area.                                                                                                         | Number of national-level 3A and above scenic spots/total number of villages*100%                                                                                |
| Primary and secondary education level (D16)        | Good construction of basic education can ensure that rural residents enjoy good educational conditions.                                                                                                   | Number of primary and secondary school teachers/number of primary and secondary school students*100%                                                            |
| Cultural Infrastructure Construction (D17)         | Shows the level of construction of basic cultural service facilities in the study area.                                                                                                                   | Number of libraries and cultural stations/total number of villages*100%.                                                                                        |
| Intensity of pesticide use in agriculture (D18)    | An indicator of the degree of soil and water contamination in the study area.                                                                                                                             | Pesticide use/crop sown area                                                                                                                                    |
| Intensity of fertilizer use in agriculture (D19)   | An indicator of the degree of soil and water contamination in the study area.                                                                                                                             | Agricultural fertilizer use/crop sown area                                                                                                                      |
| Sewage treatment situation (D20)                   | Shows the current water treatment capacity of the study area.                                                                                                                                             | Sewage treatment volume ÷ total sewage discharge*100%                                                                                                           |
| Air Quality (D21)                                  | Visually reflects the current air quality level of the study area for that year.                                                                                                                          | Number of days with good air quality/total number of days of annual monitoring × 100%                                                                           |
| Level of forest cover (D22)                        | High forest cover and good ecological environment of the area.                                                                                                                                            | Forest area/total land area*100%                                                                                                                                |

## Appendix B

**Table A2.** The expertise and sphere of selected 10 experts.

| Respondent | Expertise              | Sphere                                                     |
|------------|------------------------|------------------------------------------------------------|
| R1         | Human geography        | Researcher in Sun Yat-sen University                       |
| R2         | Human geography        | Staff of county management                                 |
| R3         | Human geography        | Researcher in Zhejiang Agriculture and Forestry University |
| R4         | Urban planning         | Researcher in Zhengzhou University                         |
| R5         | Urban planning         | Researcher in Zhejiang Agriculture and Forestry University |
| R6         | Urban planning         | Designer working in ZUUP                                   |
| R7         | Urban planning         | Designer working in ZUUP                                   |
| R8         | Urban planning         | Staff of county management                                 |
| R9         | Urban planning         | Staff of county management                                 |
| R10        | Tourism management     | Researcher in Zhejiang Agriculture and Forestry University |
| R11        | Tourism management     | Researcher in Zhejiang Agriculture and Forestry University |
| R12        | Forestry               | Researcher in Zhejiang Agriculture and Forestry University |
| R13        | Forestry               | Researcher in Zhejiang Agriculture and Forestry University |
| R14        | Landscape architecture | Designer working in ZUUP                                   |
| R15        | Landscape architecture | Designer working in ZUUP                                   |

## Appendix C

**Table A3.** Moran's I value calibration standard.

| Z Score          | p Value | Confidence Interval |
|------------------|---------|---------------------|
| <−1.65 or >+1.65 | <0.10   | 90%                 |
| <−1.96 or >+1.96 | <0.05   | 95%                 |
| <−2.58 or >+2.58 | <0.01   | 99%                 |

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