Research on Suburban Rural Landscape Function Trade-off and Synergistic Relationship under the Background of Yangtze River Delta Integration Development: A Case Study of Qingpu in Shanghai

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Abstract. The rapid development of regional integration strategy and urbanization construction in the Yangtze River Delta has led to significant changes in the function of rural landscape, yet little attention has been paid to the evolving relationship of landscape function in this region. In order to effectively address the local evolution characteristics of rural landscape functions within the integrated development of the Yangtze River Delta, and propose targeted scientific development and construction strategies, this study focuses on Shanghai Qingpu District as a demonstration zone, selecting four time nodes from 1990 to 2020. The research utilizes factor analysis method, fuzzy comprehensive evaluation method, pearson correlation coefficient method and geographical weighted regression method to explore the spatiotemporal evolution of trade-offs and synergies between rural landscape functions in Qingpu District. The findings reveal that: (1) economic development has replaced agricultural production as the primary function in Qingpu District; (2) there are evident trade-offs and synergies among different functions of rural landscape which change over time; (3) multi-functional balance and synergistic relationships exhibit significant geographic variability in spatial pattern, influenced by the equilibrium between economic development and ecological protection. However, it is noted that there are discontinuities based on static time nodes, incomplete selection of representative landscape function evaluation indicators, and neglect for differences in subjective needs which may lead to inaccurate research results. These issues will be addressed gradually in subsequent studies.

Keywords: suburban countryside; rural landscape; trade-off and synergy; Yangtze River Delta integrated development

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1 INTRODUCTION

As a multi-functional ecosystem, rural landscape has a variety of social, economic and ecological functions [1]. With the rapid development of social economy and the rapid advancement of urbanization construction, human's demand for landscape functions and activities has gradually increased from singularity to diversity. Under the restriction of limited natural ecosystems, the pursuit of multiple goals has led to the continuous strengthening of the compound of landscape functions and relationships [2], showing a "trade-off" and promotion of "synergy" [3]. Trade-off refers to the reduction or growth of a function leading to the increase or decrease of related functions, while synergy refers to the simultaneous reduction or increase of two or more functions [4]. As the suburban countryside with the diffusion of urban functions, the material and intangible cultural elements of urban and rural areas work together here, and it has become the area with the most intense collision between urban and rural areas [5], with comprehensive functions of agricultural production, social life, ecological regulation, leisure and entertainment [6][7][8]. Rural landscape has also undergone unprecedented changes, which are not only reflected in the material aspects of rural land use, architectural form, village pattern, etc., but also in the functional positioning and mutual relationship of landscape, whose trade-off and synergistic relationship are increasingly complex [9]. In 2018, the Three-year Action Plan for the Integrated Development of the Yangtze River Delta Region (2018-2020) was issued, and the "integrated development of the Yangtze River Delta Region" was elevated to a national strategy. In 2019, The State Council issued the Outline of the Plan for Regional Integrated Development of the Yangtze River Delta, which clarified the strategic positioning of the Yangtze River Delta for regional integrated development and made it a strong and dynamic growth pole and high-quality development model area for national development. In February 2023, the "Yangtze River Delta Eco-Green Integrated Development Demonstration Zone Territorial Space Master Plan (2021-2035)" was approved, proposing ecological priority, green development as the orientation, based on regional resource endowments and characteristics of Jiangnan water towns, to protect and inherit cultural and natural values. Therefore, clarifying the temporal and spatial change characteristics of the rural landscape function balance and synergy in the Yangtze River Delta integration region has become the key to releasing the new driving force of rural development, rationally developing rural landscape resources, realizing the "win-win" of rural ecological protection and economic development, improving the overall regional functions and benefits, and playing the role of an example of urban-rural integration and development [10][11]. Thus driving the Yangtze River Delta three provinces, one city and rural linkage development.

However, most domestic and foreign scholars study the relationship between landscape functions mainly from the perspectives of land use [12], landscape pattern change [13], agricultural landscape function [14] and ecosystem service function [15], and explore the connotation [16] and type of function and service [17]. Various models [18] were used to conduct special evaluation of rural landscape functions such as terraced landscape [19], plateau hilly area [20], arid area [21], cultivated land land-

scape [22] and agricultural area [23] [24]. However, due to the extensive use of temporal correlation analysis and the neglect of functional space interaction, the spatial and temporal differences of landscape functional relationships in different regions cannot be accurately analyzed, and adaptive improvement measures cannot be proposed for different regions. At the same time, many studies focus on the differentiation and evolution of some special types of landscape functions, failing to develop the change of landscape functions and targeted optimization paths of ordinary rural areas in the process of urbanization. Few studies have been done on the changing characteristics and rules of the landscape functional relationship in rural areas where the problems of urban and rural development are more complicated and the contradictions are more prominent in the Yangtze River Delta integrated development region. In order to scientifically analyze the differentiation of different street and township landscape functions in the process of rural development in the Yangtze River Delta region from the perspective of different spatio-temporal evolution, specific measures to promote the synergistic development of different rural landscape functions are put forward. This study attempts to introduce the trade-off and collaborative research methods commonly used in ecology into the relationship analysis of rural landscape functions. Taking 184 administrative villages in Qingpu District of Shanghai, a demonstration area for the integrated development of the Yangtze River Delta, as an example, the correlation coefficient analysis of regional landscape functions in time is combined with bivariate spatial autocorrelation. The study of the spatial and temporal changes of the trade-off and coordination relationship between typical rural landscape functions in this region from 1990 to 2020 not only has important academic value for understanding the urban-rural relationship and the evolution of rural functions, but also has important guiding significance for rural revitalization and rural landscape construction, and provides scientific reference for realizing the integrated development of the Yangtze River Delta region and playing the role of demonstration zones.

2 OVERVIEW OF THE STUDY AREA

Qingpu District is located in the southwest corner of Shanghai, between the lower reaches of Taihu Lake and the upper reaches of Huangpu River, between 120°53'~121°17' east longitude and 30°59'~31°16' north latitude, with a total area of 668.54 square kilometers, flat terrain, altitude of 2.8-3.5 meters, and the daily average temperature of about 17.6°C. The water network is densely covered and rivers run through the territory. Dianshan Lake in Qingpu District is 46.84 square kilometers, rich in species resources and high vegetation coverage, which is an important ecological barrier for Shanghai. In 2020, the GDP of Qingpu District is 119.401 billion yuan, calculated at comparable prices, an increase of 3.8% over the previous year, and the growth rate is the third in the city. The added value of the primary industry is 797 million yuan; The added value of the secondary industry was 42.162 billion yuan; The tertiary industry added 76.442 billion yuan. Qingpu District has jurisdiction over 3 streets and 8 towns: Xia-yang Street, Yingpu Street, Xianghuaqiao Street, Zhaoxiang Town, Xujing Town, Huaxin Town, Chonggu Town, Baihe Town, Zhujiajiao Town,

Liantang Town, and Jinze Town, with jurisdiction over 184 administrative villages and 157 communities (Figure 1).

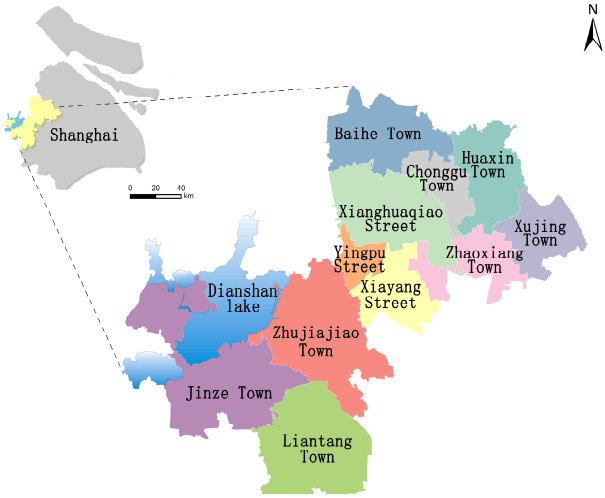

Fig. 1. Location map of Qingpu District, Shanghai.

3 RESEARCH METHODS AND DATA SOURCES

3.1 Classification Basis for Suburban Rural Landscape Function

The core of rural landscape function classification lies in the in-depth analysis of the in-teraction between rural landscape, human activities, and ecological systems. Rural land-scape is not only the carrier of coupling and interaction of natural elements and social activities, but also the place for cultural, economic, and ecological integration and de-velopment. Based on the causes and division scheme of rural landscape func-tion [25], combined with the evaluation system of natural resources function [26], and according to the social, economic and regulatory functional characteristics of land-scape, this study constructs the framework of production function, living function and ecological function of rural landscape function evaluation target layer, and refines the criteria layer and index layer index of rural landscape function.

Production Function of Rural Landscape.

This function mainly focuses on the production activities in rural areas, focusing on the economic value provided by rural landscape, including agricultural production function and economic development function. Agricultural production function is the core of rural landscape production function, involving the production of food, raw materials, medicine and other agricultural products. Economic development function goes beyond traditional agricultural production, covering non-agricultural economic activities such as tourism, handicrafts and township enterprises, reflecting the poten-

tial value of rural landscape in local economic development [27], and reflecting the importance of rural areas to national and regional development.

Living Function of Rural Landscape.

This function emphasizes the role of rural landscape in maintaining and improving people's quality of life, including space, cultural and aesthetic dimensions, including space bearing function and landscape aesthetic function. Among them, the space bearing function focuses on how rural landscape provides space for residents to live, communicate and carry out activities, and how to reasonably arrange to meet the needs of the community. The landscape aesthetics function focuses on the aesthetic value and cultural value of rural landscape, reflecting how rural landscape provides spiritual comfort, enhances the sense of community identity and strengthens the sense of place.

Ecological Function of Rural Landscape.

This function highlights the role of rural landscape in maintaining and enhancing the stability of the ecological system, and emphasizes the role in harmonious coexistence with nature. It is divided into ecological regulation function and environmental maintenance function. Ecological regulation function mainly involves the role of rural landscape in climate regulation, water resource conservation, soil protection, biodiversity maintenance, etc., which is the key of ecological function of rural landscape [28]. Environmental maintenance function pays more attention to protecting and improving the environ-mental quality of rural landscape, such as air and water purification, pest control, organic waste recycling, etc., to ensure the long-term stability and sustainable development of rural ecological environment.

3.2 Design of Evaluation Index for Rural Landscape Function

This study adopts the factor analysis method to set the weight of each index. The specific evaluation index and its weight are shown in Table 1.

Table 1. Evaluation index system for rural landscape function.

Objective layer	Criterion layer	Indicator layer	Calculation method or index meaning	Indicator direction	Indicator weight
Production Function	Agricultural Production Function	Agricultural Productivity	Total Agricultural Production/Total Cultivated Area	+	0.15
		Land productivity	Agricultural Production/Total Cultivated Area	+	0.10
		Degree of Agricultural Mechanization	Number of Agricultural Machinery in Use/Total Cultivated Area	+	0.05

	Economic Development Function	Rural Tourism Income Rate	Tourism Income/Rural Tourism Trips	+	0.10
		Per Capita Income from Non-agricultural Economic Activities	Total Income from Non-agricultural Economic Activities/Number of People Engaging in Non-agricultural Economic Activities	+	0.05
		Rural Enterprise Size	Total Number of Rural Enterprises/Total Rural Area	+	0.15
Living Function	Space Carrying Function	Per Capita Living Area	Total Rural Living Area/Total Rural Population	+	0.15
		Per Capita Public Space	Total Public Space Area/Total Rural Residents	+	0.10
		Degree of Infrastructure Development	Total Rural Infrastructure/Total Rural Area	+	0.05
	Landscape Aesthetic Function	Aesthetic Evaluation Score	Average Score of Experts and Residents' Questionnaire	+	0.10
		Cultural Heritage Protection Status	Number of Rural Cultural Heritage/Number of Damaged Cultural Heritage		0.05
Ecological Function	Ecological Adjustment Function	Climate Adjustment Factor	Correlation Index of Regional Vegetation Coverage with Rainfall and Temperature Fluctuation	+	0.15
		Water Resources	Regional Water Volume/Total Regional Area	+	0.10
	Environmental Maintenance Function	Degree of Biodiversity Protection	Number of Existing Species in Rural Areas/Number of Extinct or Endangered Species	+	0.05
		Air Quality Index (AQI)	The reciprocal of the average concentrations of PM2.5, PM10, SO_2, NO_2, O_3	-	0.15
		Degree of soil pollution	Concentration of heavy metals, pesticide residues and other pollutants in soil	-	0.10
		Pest control effectiveness	Effective control of rural pest species/pest species	+	0.05

3.3 Multi-functional Evaluation Methods of Suburban Rural Landscape

Fuzzy Comprehensive Evaluation Method.

The comprehensive evaluation method of fuzzy mathematics transforms qualitative evaluation into quantitative evaluation by using the membership theory of fuzzy mathematics. This method is especially suitable for dealing with the problems that are restricted by many factors and are fuzzy and difficult to quantify. As rural landscape function is a complex dynamic process affected by multiple complex factors and dif-

ferent indicators, it is impossible to distinguish good from bad simply. Therefore, based on the determined function classification and evaluation index system, this study adopts fuzzy comprehensive evaluation method for comprehensive evaluation of different single functions, and the calculation formula is as follows [29]:

$$F_i=W\times R \tag{1}$$

where F_i represents the total evaluation value of the i-th function; W is the index weight matrix; R is the standardized index value matrix of the i-th function. This formula provides a comprehensive evaluation value for each function by integrating the uncertainty of each index through the fuzzy evaluation method.

Pearson Correlation Coefficient Analysis.

Pearson correlation coefficient analysis is a statistical measure used to measure the degree of linear correlation between two variables in various natural and social phenomena, showing the direction and strength of the relationship between the two variables. Its range is between [-1,1], and the correlation coefficient is positive, indicating that there is a positive correlation between the two variables, that is, the increase of one variable. The other variable also increases; When the correlation coefficient is negative, it indicates that there is a negative correlation between two variables, that is, one variable increases and the other variable decreases. There are potential conflicts, trade-offs or synergies relationships among landscape functions [30]. Therefore, Pearson correlation coefficient method can precisely quantify the temporal evolution pattern of trade-offs and synergies relationship between the two functions in rural landscape. The formula is as follows:

$$C_{ij}=p(F_i,F_j) \tag{2}$$

Where C_{ij} represents function i and function j, and is the Pearson correlation coefficient, with a range of -1 to 1, indicating positive or negative correlation between functions. The value close to 1 indicates positive correlation, while the value close to -1 indicates negative correlation.

Geographical Weighted Regression Model.

Geographical Weighted Regression model is a localized linear regression approach that captures spatial change relationships. It generates descriptive local relations within each study area segment to accurately explain the local spatial relation and heterogeneity of variables. Different internal and external factors have distinct impacts on the evolution of rural landscape functions across diverse geographical spaces. Consequently, the GWR model effectively reveals various trade-offs and synergies in geographic contexts. The local regression of spatial variability is reflected by the following formula:

$$Y_i=\beta_{0i}+\sum_{k=1}^{n}\beta_{ki}F_{ki}+\epsilon_i \tag{3}$$

where Y_i is the total function value of the i-th spatial unit, β_{ki} is the coefficient of the k-th function in the i-th spatial unit, F_{ki} is the evaluation value of the k-th function, is the function in the i-th spatial unit, and ϵ_i is the error term in the i-th spatial unit.

3.4 Data Sources and Processing

The spatial geographic data sources required to study the evolution of the trade-off and synergistic relationship of suburban rural landscape are as follows: (1) from Qingpu District Planning and Land Bureau, covering 1:5000 land use status map from 1990 to 2020 [31];(2) Qingpu District Land Use General Planning Database (1990-2020);(3) Land Statistics Standing Account (1990-2020).The collection of social statistical data includes the following information: (1) Qingpu District Statistical Yearbook (1990-2020);(2) Qingpu District Statistical Yearbook of Townships (1990-2020);(3) Qingpu District Agricultural Statistical Yearbook (1990-2020);(4) Qingpu District Industrial Development Report (1990-2020);(5) Qingpu District Forestry Statistical Yearbook, Qingpu District Environmental Survey Report, Shanghai Qingpu District National Economic and Social Development Statistical Communique, etc.

The data processing process is as follows: (1) According to the Second National Land Survey Technical Regulations (TD/1014-2007), the land types in each period are divided into eight categories: cultivated land landscape, garden landscape and woodland landscape [32]; (2) According to the administrative boundary in 2020, the administrative boundary in different periods is fitted and adjusted; (3) Since part of the water surface of Dianshan Lake belongs to Kunshan City and Qingpu District, it is divided into Zhujiajiao Town and Kanazawa Town according to 1/4 of the area; (4) Based on the ecological environment capacity index, the landscape ecological land environmental capacity is evaluated; (5) 184 administrative villages are selected as spatial statistical units; (6) Exploratory data analysis method is used to deal with outliers; (7) Based on Rook adjacent principle, the spatial autocorrelation weight is determined.

4 RESULTS AND ANALYSIS

4.1 Results of Multi-functional Evaluation of Rural Landscape

A fuzzy comprehensive evaluation was carried out on the construction of 17 evaluation indicators, and the average values of the "three life" target layer functions and the landscape sub-functions of 6 criterion layers of 184 rural units in Qingpu District in 4 years were calculated to obtain the multi-functional comprehensive evaluation results of rural landscape in Qingpu District, as shown in Table 2 below.

Table 2. Results of comprehensive evaluation of rural landscape function in Qingpu District.

Category	Functionality	1990	2000	2010	2020
Target	production function	0.537	0.632	0.654	0.669

layer	Life function	0.516	0.538	0.558	0.582
	Ecological function	0.594	0.494	0.325	0.374
Criterion layer	Agricultural production function	0.647	0.595	0.442	0.337
	Economic development function	0.532	0.718	0.881	0.937
	Space carrying function	0.417	0.538	0.638	0.698
	Landscape aesthetic function	0.602	0.504	0.314	0.377
	Ecological adjustment function	0.647	0.409	0.298	0.311
	Environmental sustainability function	0.559	0.338	0.237	0.299

(1) From 1990 to 2020, the rural landscape functions of Qingpu District showed variability. From the functional point of view, the production function is higher than the life function, and the life function is higher than the ecological function. In 2020, the economic development function reached a peak of 0.937, and in 2010, the environmental sustainability function dropped to a low of 0.237. In the study period, the average value of economic development function was the highest at 0.767, followed by the average value of spatial carrying function at 0.573, and the average value of environmental sustainability function was the lowest at 0.358.

(2) The temporal variation of rural landscape function was significant during the study period. The production function and living function increased year by year, but the ecological function showed a weak rebound after the decline. Both the economic development function and the spatial carrying function are increasing year by year. From 1990 to 2020, the economic development function increased by 76.1%, while the spatial carrying function increased by 67.4% during the same period. Agricultural production function decreased by 0.31, or 31.1%. The landscape aesthetic function, ecological adjustment function and environmental sustainability function all showed the fluctuation of decreasing first and then increasing, and the ecological adjustment function fluctuated the most. This means that the agricultural production function of Qingpu District is no longer dominant, and the economic development function is more important.

4.2 Time Pattern of Landscape Multifunctional Trade-off and Synergistic Relationship

Based on equation (2), the temporal variation trend of multifunctional trade-off and synergy relationship in rural landscape is obtained, as shown in Table 3 below.

Table 3. Temporal pattern of functional trade-off and synergistic relationship of rural landscape in Qingpu District.

Landscape Function Type	1990	2000	2010	2020
Production and living	0.58	0.66	0.75	0.82

Production and ecology	-0.52	-0.60	-0.68	-0.63
Life and Ecology	0.45	0.38	0.28	0.23
Agricultural production and economic development	-0.78	-0.80	-0.83	-0.85
Economic development and landscape aesthetics	0.55	0.48	0.40	0.34

(1) From 1990 to 2020, the synergistic relationship between production and life has increased year by year, indicating that production and life functions are more complementary in the rural landscape.

(2) The trade-off between production and ecology strengthened from -0.52 in 1990 to -0.68 in 2010 and moderated to -0.63 in 2020, which may indicate that increased production has put some pressure on ecology, but this pressure has lessened in recent years.

(3) The synergistic relationship between life and ecology decreases year by year from 0.45 in 1990 to 0.23 in 2020, and the positive correlation between life function and ecological function decreases year by year.

(4) The trade-off between agricultural production and economic development continues to be strong, from -0.78 in 1990 to -0.85 in 2020, indicating that agricultural production and economic development are difficult to develop together in the realization of rural landscape functions.

(5) The synergistic relationship between economic development and landscape aesthetics decreased from 0.55 in 1990 to 0.34 in 2020, indicating that the synergistic relationship between rural landscape aesthetics, which is positively correlated with economic development, has weakened year by year. It can be concluded that there are obvious trade-offs and synergies between different functions of rural landscape in Qingpu District, and these relationships change in different directions with the passage of time.

4.3 Spatial Pattern of Landscape Multifunctional Trade-off and Synergistic Relationship

Table 4. Temporal pattern of functional trade-off and synergistic relationship of rural landscape in Qingpu District.

Space unit	production and living	Production and ecology	Life and ecology	agricultural production and economic development	Economic development and landscape aesthetics
Xiayang Street	0.68	-0.54	0.43	-0.77	0.50
Yingpu Street	0.72	-0.50	0.46	-0.80	0.53
Xianghuaqiao Street	0.65	-0.58	0.40	-0.75	0.47
Zhujiajiao Town	0.70	-0.52	0.44	-0.78	0.52

Liantang Town	0.67	-0.53	0.42	-0.76	0.49
Jinze Town	0.71	-0.51	0.45	-0.79	0.51
Zhao Xiang Town	0.69	-0.55	0.43	-0.77	0.50
Xujing Town	0.70	-0.52	0.44	-0.78	0.52
Huaxin Town	0.68	-0.54	0.43	-0.77	0.50
ChongGu Town	0.69	-0.53	0.42	-0.76	0.48
Baihe Town	0.67	-0.56	0.41	-0.75	0.49

In combination with the specific geographical location and administrative division of Qingpu District, the spatial pattern of functional trade-offs and synergistic relationships in the landscape was studied by using the geographical weighted regression (GWR) method based on formula (3), as shown in Table 4. The results show that the multi-function trade-off and synergistic relationship of rural landscape in Qingpu District show significant geographical variability in spatial pattern, and are affected by the trade-off between economic development and ecological protection.

(1) Yingpu Street, Zhujiajiao Town, Jinze Town and Xujing Town have stronger synergistic relationship between production and life functions, while Xianghuaqiao Street has weaker production and life functions.

(2) The trade-off between production and ecology in Xianghuaqiao Street and Baihe Town is strong, indicating that the production function and ecological function of the landscape in this region are difficult to achieve together.

(3) The synergistic relationship between life and ecological functions in Xianghuaqiao Street and Baihe Town is relatively weak, which reflects the certain contradiction between ecological protection and residents' life.

(4) With the development of economy, the synergistic relationship between economic development and landscape aesthetics of most spatial units is not strong, weaker than the relationship between production and life functions, but generally higher than the synergistic relationship between life and ecological functions.

5 CONCLUSION AND DISCUSSION

5.1 Conclusion

With the development of economy, the expectation of rural residents on the quality of life and the environment has gradually increased, and the rural landscape has been promoted to the direction of multi-functionality and synergy. In addition, the integrated development of the Yangtze River Delta region has promoted the urbanization process, strengthened the connection between rural and urban areas, and provided new opportunities and challenges for the coordinated evolution of rural landscapes. The economic and social changes in Qingpu area have a profound impact on the rural landscape. This evolution involves economic growth and is driven by multiple factors

such as policies, technology and globalization related to the integrated development of the Yangtze River Delta region. The tradeoffs and co-evolution of rural landscapes are not linear, and their complexity involves multiple trade-offs and conflicts at economic, social and ecological levels. Such trade-offs and conflicts are not only reflected in space, but also in the speed and direction of evolution at the time level. At the same time, the balance and cooperative evolution of rural landscape also reflect the changes of rural landscape value, the changes of rural communities and residents' living environment and lifestyle. Through the in-depth study of the landscape balance and collaborative evolution of 184 administrative villages in Qingpu District, the following three conclusions are drawn:

(1) The economic development of Qingpu District has surpassed agricultural production as the dominant force. Compared with the past few decades, Qingpu District has undergone a transformation from agriculture-oriented to diversified economic development, revealing that the evolution of economic activities and lifestyle has become the main driving factors for the change of rural landscape. The landscape construction of demonstration areas should be rationally planned in conjunction with the changes of economic activities and lifestyle.

(2) Functional tradeoffs and synergistic relationships of rural landscape are different in time and space, and these relationships show significant changes over time. Especially with the rapid economic development and social changes, the complementarity and tradeoff between different functions of rural landscape show different trends.

(3) The spatial synergistic relationship of rural landscape in Qingpu District showed significant geographic variability, and the tradeoff and synergistic relationship of rural landscape in different regions were jointly affected by geographical location, economic development level and ecological factors.

In summary, this paper takes 184 administrative districts of Qingpu District in the western suburbs of Shanghai as examples to deeply explore the characteristics of the collaborative evolution of rural landscape in the context of the integrated development of the Yangtze River Delta region, which is conducive to a more comprehensive understanding of the sustainable development of urban and rural areas in the integrated development region of the Yangtze River Delta region, and provides scientific basis for relevant decision-making.

5.2 Discussion

In the regional scale geospatial expression, this study still has some shortcomings.

(1) Static time node selection problem. The time nodes of the study were selected in 1990, 2000, 2010 and 2020. As the differences of functional values are highly dependent on time nodes, the subtle differences of landscape functions in each decade cannot be fully reflected for the time being. In the later stage, the density of nodes will be increased in relevant studies to improve the continuity and precision of experimental results.

(2) Integrity of functional indicators. The comprehensiveness of indicators is the basis for the accurate representation of results. Six functions representing rural land-

scape functions and 17 indicators are selected from the perspective of production, life and ecology, but the functions of rural landscape are compound communities composed of multiple functions and factors, such as cultural inheritance functions, social support functions, spiritual and emotional functions and indicators, etc. [33]. In the later stage, other major associated indicators will be verified one by one in related studies to further improve the comprehensiveness of the indicator system.

(3) The difficulty of quantitative representation of subjective needs. The hierarchy and diversity of human needs make it difficult to represent them. The study did not consider factors such as the will and preferences of groups and individuals. At the same time, it depicted the landscape aesthetic function from the perspective of demand and demand level, ignoring the unique, local and different factors of rural landscape aesthetics. In the follow-up study, we will try to combine qualitative and quantitative methods to quantify the subjective indicators in order to improve the comprehensiveness of the research conclusions.

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