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RECEIVED 27 July 2025
ACCEPTED 08 September 2025
PUBLISHED 26 September 2025

CITATION

Liu Z and Chen C (2025) Can the integration of agriculture and tourism improve the rural human settlement environment?—based on panel data of 30 provinces over 2008–2022 in China.
Front. Sustain. Food Syst. 9:1673999.
doi: 10.3389/fsufs.2025.1673999

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Can the integration of agriculture and tourism improve the rural human settlement environment?—based on panel data of 30 provinces over 2008–2022 in China

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Comprehensively improving the rural human settlement environment is one of the important aspects of rural revitalization in China. Building beautiful and livable villages is of vital importance to the well-being of farmers. Based on the panel data of 30 provinces in China from 2008 to 2022, this study uses the entropy weight TOPSIS model to measure the level of rural human settlement environment (RHSE), and employs the entropy value method, factor analysis method and grey correlation degree model to evaluate the level of agriculture tourism integration (ATL). On this basis, the dynamic spatial Durbin model and threshold effect model are used to test the impact of ATL on RHSE. The results show: ① RHSE and ATL have significant spatial clustering characteristics. Given the dynamic and continuous characteristics of RHSE, the dynamic spatial Durbin model can better reveal the relationship between the two. ② ATL has a significant direct impact and spillover effect on RHSE. That is, agriculture tourism integration can effectively improve the rural human settlement environment. And in the four regions of the east, central, west and northeast, the direct effect in the central region is the strongest, and the spillover effect in the eastern region is the most significant. ③ The impact of ATL on RHSE has a prominent stage and economic dependence, demonstrating typical nonlinear threshold characteristics. The impact effect of ATL on RHSE shows a dual threshold characteristic as the ATL increases, and a single threshold characteristic as the regional economic level improves. Based on above results, this paper pions that the government should strengthen policy design, implement differentiated agriculture tourism integration paths based on the regional characteristics of the eastern, central, and western regions, and promote the improvement of the rural human settlement environment. Meanwhile, it should establish a cross-regional collaborative governance mechanism and implement the Talent Revitalization Project to enhance the level of agriculture tourism integration and its sustained driving force for environmental improvement.

KEYWORDS

integration of agriculture and tourism, rural human settlement environment, spillover effects, dynamic spatial Durbin model, threshold effect model

1 Introduction

The rural human settlement environment (RHSE) consists of natural, artificial and social elements, comprehensively reflecting the rural environment, ecology and social management conditions (Cheng et al., 2024). Therefore, the rural human settlement environment is a complex combination of material and non-material elements that support farmers' daily lives. According to UN data, farmers account for over half of the global population, and impoverished farmers make up 79% of the global poor population. The poverty rate in rural areas is more than three times that of urban areas. Among the 2 billion people worldwide who cannot access basic medical services, 70% live in rural areas (Lin and Hou, 2023). The energy penetration rate in rural areas is approximately 75%, while in urban areas it is as high as 96% (Zhang et al., 2022). In fact, all countries around the world have experienced the decline of rural human settlement environments. In countries such as the United States, Canada, Sweden, Australia, China and Japan, the rapid urbanization process has seriously exacerbated the population, social and environmental contradictions in rural areas, and villages are gradually declining. In China, for a long time after the reform and opening up, due to excessive emphasis on rapid economic growth while neglecting the sustainable development of the ecological environment, rural areas experienced environmental deterioration, aging infrastructure and intensified pollution problems (Yu F. et al., 2022; Zhao et al., 2019). How to improve the rural human settlement environment is an important foundation for improving farmers' quality of life and promoting the revitalization and development of rural areas.

Improving the rural human settlement environment is an important part of China's comprehensive implementation of the rural revitalization strategy and the realization of agricultural and rural modernization. In recent years, China has placed greater emphasis on improving the rural human settlement environment and has successively proposed guiding plans such as building a new socialist countryside and building beautiful villages. In December 2021, the General Office of the Central Committee of the Communist Party of China and the State Council issued the "Five-Year Action Plan for the Improvement and Enhancement of rural human settlement environment (2021–2025)," attempting to promote the improvement of rural human settlement environment through policy measures. The report of the 20th National Congress of the Communist Party of China states that "the layout of rural infrastructure and public services should be coordinated, and beautiful and livable rural areas should be built." However, due to long-term governance failures, the overall rural human settlement environment is still at a relatively low level, which has become an important shortcoming of China's "agriculture, rural areas, and farmers" issues. How to improve the rural human settlement environment and promote the sustainable development of rural human settlement environment has become a topic of widespread concern.

Researches on human settlement environment can be traced back to the 19th century. At that time, "human settlement environment" had not yet been formally proposed as an academic term; it was only scattered and mixed in the works of sociology, architecture, geography, and urban and rural planning in various forms. Moreover, influenced by the idea that "cities are the advanced stage and inevitable trend of human settlement development," the research subjects mainly focused on cities for a long time. It was not until Doxiadis (1968) published "Introduction to Human Settlement Environment Studies" that the discipline of human settlement environment was officially established. He believed that human settlement

environment is the foundation of human survival and development, and are the most intimate and specific material exchange and emotional communication space between humans and the natural environment. Since then, scholars have continuously enriched the research results on rural human settlement environment from perspectives such as urban planning, geography, ecology, environmental economics, and public health, and the research content covers various aspects such as the evolution of the settlement pattern, planning and improvement, development and transformation, and sustainable development of rural human settlement environment (Rigg, 1985; Ha, 1989; Foster, 1993; Cornelissen et al., 2001). With the development of the economy and society, the gap between urban and rural areas in developed countries has been continuously narrowing, and the boundaries between urban and rural areas have become increasingly blurred. Research specifically targeting rural human settlement environment has gradually weakened (Kim et al., 2003; Fidler et al., 2011; Komeily and Srinivasan, 2015; Kaplan et al., 2019).

In the 1990s, Chinese researcher Wu (1990, 1996, 1997) introduced Doxiadis' theory into China. Due to the differences in social structure and development stage, the focus of research in China was different from that in Western countries. With the rapid advancement of China's reform and opening up and industrialization and urbanization, the level of urban and rural environmental construction in China has increasingly become polarized in the 21st century. Following the unexpected arrival of a series of "rural diseases" along with "urban diseases," including infrastructure aging, lagging economic development, environmental pollution, and hollowing out (Liu, 2018), the issue of rural living environment quality has attracted much attention once the human settlement environment science theory was introduced. Initially, related research mainly focused on architectural and urban planning perspectives, covering rural architectural layout, scale, form, and residential design (Zhou et al., 2011; Li et al., 2007). Later, as environmental science for human settlements integrated with multiple disciplines, it further expanded to the evolution process and influencing factors of rural human settlement environment (Wang et al., 2005; Sun et al., 2020; Ye et al., 2018; Zhang et al., 2017; Yu, 2019; Wang et al., 2021; Yu et al., 2022), as well as the supply mechanism of basic rural public services (Cui et al., 2025). Since the implementation of the rural revitalization strategy, quantitative evaluation research on the quality of rural human settlement environment has gradually become more abundant, such as constructing an evaluation index system for measurement (Wu, 2019; Wang and Zhu, 2023; Yu F. et al., 2022; Sepahvand et al., 2021). With the development of digital technology, the digital governance of rural human settlement environment has also attracted the attention of scholars. Du and Jiao (2023) proposed measures such as introducing modern information technology, paying attention to public environmental needs, and building an environmental cooperation network to improve rural human settlement environment. In addition, scholars have also explored governance models from the perspectives of villagers' councils and grassroots organizations (Ye et al., 2018; Wang and Zhu, 2023; Li and Jia, 2025; Li et al., 2021, 2022; Zhang, 2021; Zhu, 2023). However, research from the perspective of rural industrial development exploring the improvement paths of rural human settlement environment is still relatively lacking.

Besides, industrial integration is an important means to promote the transformation of rural production methods and has received high attention from all levels of government in China. As the process of rural industrial integration accelerates, new industries and new business forms related to agriculture keep emerging, effectively supporting rural

industrial development and the construction of harmonious villages. Among them, agriculture tourism integration (ATL) stands out particularly. With the integrated development of agriculture and tourism, its impact on rural economy, society and environment has received increasing attention: Firstly, in terms of its economic effect, scholars have found that establishing an effective connection between agriculture and tourism will not only bring new market space and consumer demand, but also promote the high-quality development of tourism and agricultural products (Testa et al., 2019; Tew and Barbieri, 2012; Lupi et al., 2017; Ammirato et al., 2020). Although the agricultural products needed by tourism only account for a small part of the total agricultural products, it still plays a key role in ensuring the quality of agricultural products (Schilling et al., 2012; Valdivia and Barbieri, 2014). Moreover, many scholars have conducted empirical studies on the impact of the integration of agriculture and tourism on rural and regional economic growth (Van Sandt and Thilmany Mcfadden, 2016). Secondly, in terms of its social impact, scholars believe that the development of agricultural tourism can provide economic incentives and stability for farmers, and improve the quality of life of rural population in mountainous areas, thereby addressing the challenges brought by population migration and economic changes (Dax et al., 2019). In addition, it is also conducive to strengthening urban–rural connections and promoting the protection of natural or cultural heritage (Streifeneder, 2016). Thirdly, in terms of its environmental impact, scholars hold different views on the ecological effects of agricultural and tourism integration. Some people believe that tourism provides another source of income for agriculture, which is conducive to the sustainable development of agriculture. The development of agricultural tourism will attract some agricultural labor force and provide funds for farmers to adopt innovative technologies, such as fertilizers, enabling farmers to expand production without increasing the frequency of cultivation or clearing new land, thereby indirectly reducing environmental degradation (Villanueva-álvaro et al., 2017). However, drawing labor from the agricultural sector may also lead to the loss of farmers with land management skills, thereby causing the deterioration of agricultural ecological environment (Solymannejad et al., 2021). Previous studies have reached opposite conclusions, so whether agriculture tourism integration can promote the improvement of rural human settlement environment still needs further verification.

By reviewing the existing literature, it can be seen that current researches have provided numerous policy measures and theoretical support for improving the rural human settlement environment. At the same time, it has also confirmed that the integration of agriculture and tourism will bring about many benefits, such as increasing farmers' income and promoting the development of agricultural total factor productivity. However, there are relatively few comprehensive analyses of the integration of agriculture and tourism on the improvement of rural human settlement environment. The integration of agriculture and tourism serves as a symbol of the integration of the three industries in rural areas. While promoting rural economic development, can it effectively improve the rural human settlement environment? What are the theoretical connections between the integration of agriculture and tourism and the improvement of rural human settlement environment? What are the characteristics of the impact of the integration of agriculture and tourism on the improvement of rural human settlement environment? This study aims to address these above questions, explore effective paths for improving the rural human settlement environment, and hope to make appropriate theoretical contributions to promoting the improvement of rural human settlement environment through the

integration of agriculture and tourism, and provide appropriate decision-making references for improving the rural human settlement environment, enhancing farmers' happiness, and achieving rural revitalization.

The marginal contributions of this study are as follows: ① most previous studies have focused on the economic and social effects of agriculture tourism integration. This study, through empirical analysis, examines the impact of agriculture tourism integration on RHSE, providing a new perspective for the sustainable development of RHSE and expanding the research framework for the effect of rural industrial integration; ② most previous studies have conducted empirical analyses using ordinary panel models. This study takes into account the spatial effect and dynamic effect of RHSE, and adopts the dynamic spatial Durbin model and dynamic threshold model to reveal the spatial spillover effect and nonlinear influence mechanism of agriculture tourism integration on RHSE.

2 Theoretical analysis and research hypotheses

2.1 Theoretical analysis

The rural human settlement environment is the core carrier of rural sustainable development, and its quality improvement relies on the synergistic optimization of ecological, production, and living systems (Liu et al., 2023). As a deeply coupled development model of agriculture and tourism, agriculture tourism integration provides driving support for the improvement of rural human settlement environment through resource integration, economic driving, industrial upgrading, social capital agglomeration, and ecological value transformation.

Through resource integration, agriculture tourism integration breaks industrial boundaries and deeply integrates rural natural resources with tourism demands. It not only promotes the protective development of the ecological base to maintain tourism attractiveness but also drives the construction of cultural facilities in the living environment through the tourism-oriented utilization of cultural resources, enriching villagers' living scenarios. Agriculture tourism integration has an economic driving advantage, generating “agricultural income increase + tourism efficiency” compound benefits, which provides financial support for ecological environment governance while feeding back into facility upgrading in the production environment and improvement of infrastructure in the living environment (Ayyildiz and Koc, 2024). Meanwhile, agriculture tourism integration promotes industrial upgrading, spawning new formats such as leisure agriculture and rural tourism, which attract the return of rural labor and enhance their skills, optimize the labor structure and quality in the production environment, and drive the transformation of traditional agriculture to green production, reducing ecological pollution. Furthermore, it can promote the agglomeration of social capital, attracting government policy inclination and social capital investment, directly improving public service levels such as medical care and education in the living environment, and enhancing the modernization level of production methods through the introduction of production technologies (Wang et al., 2024). In addition, agriculture tourism integration facilitates ecological value transformation. Through “ecological premiums” such as high prices of organic agricultural products and paid experiences of ecological landscapes, it converts the ecological environment into core tourism assets, compelling producers to maintain green production

methods to protect the ecological base, while the high-quality ecological environment enhances villagers' living comfort (Pan et al., 2024).

2.2 Research hypotheses

2.2.1 The direct effect of agriculture tourism integration on RHSE

Based on the “ecology, production, living” functional concept, the improvement of rural human settlement environment needs to balance three core goals: protection of resource base, stimulation of industrial vitality, and improvement of people's well-being. These three goals correspond to the construction dimensions of rural ecological environment, production environment, and living environment respectively, which are mutually supportive, indispensable, and collectively form an organic whole of rural human settlement environment.

Agriculture tourism integration develops projects such as sightseeing agriculture and ecological picking gardens, which require ensuring the original ecology and pollution-free characteristics of agricultural products. This forces a reduction in the excessive use of chemicals such as fertilizers, pesticides, and plastic films, gradually forming the concept of “green production” to alleviate rural land pollution. Meanwhile, the economic benefits transformed from ecological values enhance farmers' environmental awareness, promoting them to shift from passively accepting environmental protection requirements to actively participating in ecological governance, thereby improving the autonomy of rural environmental protection and further promoting the improvement of rural ecological environment (Gao et al., 2014; Wang et al., 2023). Based on this, research hypothesis H1a is proposed: The integration of agriculture and tourism may have a positive effect on the improvement of rural ecological environment.

Besides, agriculture tourism integration addresses the core bottlenecks of labor loss and backward production methods through industrial innovation. New formats spawned by integrated development, such as catering, accommodation, and agricultural experience services, significantly increase employment opportunities in rural areas, attracting the return of rural laborers who bring advanced concepts and skills. These returning laborers are more receptive to modern agricultural training, promoting the transformation of agriculture from “traditional extensive” to “intensive and socialized” mode, optimizing planting structure and facility management, and improving the overall quality of regional labor force, thus promoting the upgrading of production environment from both subjective and objective aspects (Chang et al., 2019; Ayyildiz and Koc, 2024). Based on this, research hypothesis H1b is proposed: The integration of agriculture and tourism has a positive impact on rural production environment (RPE).

Additionally, the economic and social benefits generated by agriculture tourism integration attract government policy inclination and social capital attention, improving the scientificity and rationality of rural living facilities such as road networks and water supply and drainage systems. Meanwhile, the increase in farmers' income, appreciation of collective assets, and growth of fiscal revenue provide direct financial support for the construction of living environment, which is used for residential renovation, construction of cultural centers, and improvement of public services such as medical care and

education, comprehensively enhancing the level of living environment (Khanal and Mishra, 2014; Ammirato et al., 2020). Based on this, research hypothesis H1c is proposed: The integration of agriculture and tourism may have a positive impact on rural living environment (RLE).

As a deeply coupled development model of agriculture and tourism, agriculture tourism integration can positively contribute to the improvement of rural human settlement environment by reshaping resource utilization methods, optimizing industrial development logic, and reconstructing the people's livelihood security system. Therefore, it can contribute to the improvement of the rural human settlement environment wholly. Hereby, research hypothesis H1 is proposed: The integration of agriculture and tourism may comprehensively promote the improvement of rural human settlement environment.

2.2.2 The spillover effect of agriculture tourism integration on RHSE

As it is all known that environment is a public good, with no distinct boundaries between different regions and being a shared resource. Environmental substances within one region can flow to another region through transmission media, and the resulting impacts extend beyond the local area. RHSE exhibits significant spatial correlation across regions. Firstly, when neighboring regions attach importance to the construction of RHSE, it can significantly enhance the efficiency of resource utilization in that area, reduce the emission of environmental pollutants, and improve the local environmental situation (Bigiotti et al., 2024). The improvement of human settle environment in neighboring regions can indirectly alleviate local air and water pollution caused by pollutant emissions, helping to promote the improvement of RHSE in the local area. At the same time, the improvement of local RHSE will also radiate to other regions, promoting the overall improvement of RHSE in the region. Secondly, the integration of agricultural tourism also has certain spatial stickiness. There is a convergence phenomenon in both development types and development models between neighboring regions, and the mutual learning of experiences among local governments has become an important means of development (Ćirić et al., 2021). Neighboring regions have similar economic foundations and natural conditions. When a region achieves high environmental benefits and outstanding results from agriculture tourism integration, it will provide more applicable development experiences and practical models for neighboring regions, promoting the improvement of environmental benefits from agriculture tourism integration in neighboring regions. Based on this, research hypothesis H2 is proposed as follows: The impact of agriculture tourism integration on RHSE may have spatial spillover effects.

2.2.3 The nonlinear effect of agriculture tourism integration on RHSE

In the early stage of agriculture tourism integration, the integration of agriculture and tourism mostly remained at a shallow level of resource overlay, such as simple sightseeing and picking, and rural accommodation services. At this time, agricultural production still mainly followed the traditional model, and producers focused more on short-term economic benefits. The

input of factors such as fertilizers and pesticides was difficult to reduce, and the positive effect on the rural environment had not yet emerged. When the integration level exceeded the threshold, the industrial chains of agriculture and tourism were deeply coupled. The ecological value of agricultural resources was recognized by the market. At this time, producers would actively shift to green production methods to maintain the ecological premium, thereby significantly improving the rural ecological base (Ndhlovu and Dube, 2024).

Moreover, regions with weak economic foundations face dual constraints. On one hand, insufficient agricultural tourism market demand and incomplete infrastructure make it difficult to deepen agriculture tourism integration. On the other hand, the green agricultural transformation requires investment in funds, technology, and talents, while the fiscal support capacity and payment ability of farmers in economically weak regions are limited, making green development more difficult. After the local area's economic development crosses the threshold, the upgrading of market demand drives agriculture tourism integration towards a high-quality and ecological direction. At the same time, the government and social capital increase investment in infrastructure and public services, breaking the technical and financial constraints of agricultural green production, and the improvement effect of agriculture tourism integration on the rural environment can be fully released (Hatan et al., 2021).

Therefore, the impact of agriculture tourism integration on RHSE requires sufficient integration depth and economic support capacity. The threshold values of these two variables lead to its impact presenting a nonlinear characteristic of low-level non-significance and high-level significant promotion (as shown in Figure 1). Based on this, research hypothesis H3 is proposed as follows: The impact of agriculture tourism integration on RHSE may be constrained by the

levels of agriculture tourism integration and regional economic development.

3 Research methods and data sources

3.1 Entropy weight TOPSIS method

The entropy weight method is a commonly used objective weighting method, which can to some extent avoid the influence of subjective factors and is more suitable for determining the weights of multi-dimensional indicators. The TOPSIS model is a method for approximating the ideal ranking in multi-objective decision analysis. By calculating the distance between the evaluated object and the ideal solution, the evaluation score of the object is obtained (Zhang et al., 2011). Therefore, based on the weight determination by the entropy value method and combined with the TOPSIS model, the distance between the object and the positive and negative ideal values can be effectively measured for assessment and ranking of superiority and inferiority. This study adopts the entropy weight TOPSIS method to measure the RHSE level and the agriculture tourism integration level. The specific operation process is as follows:

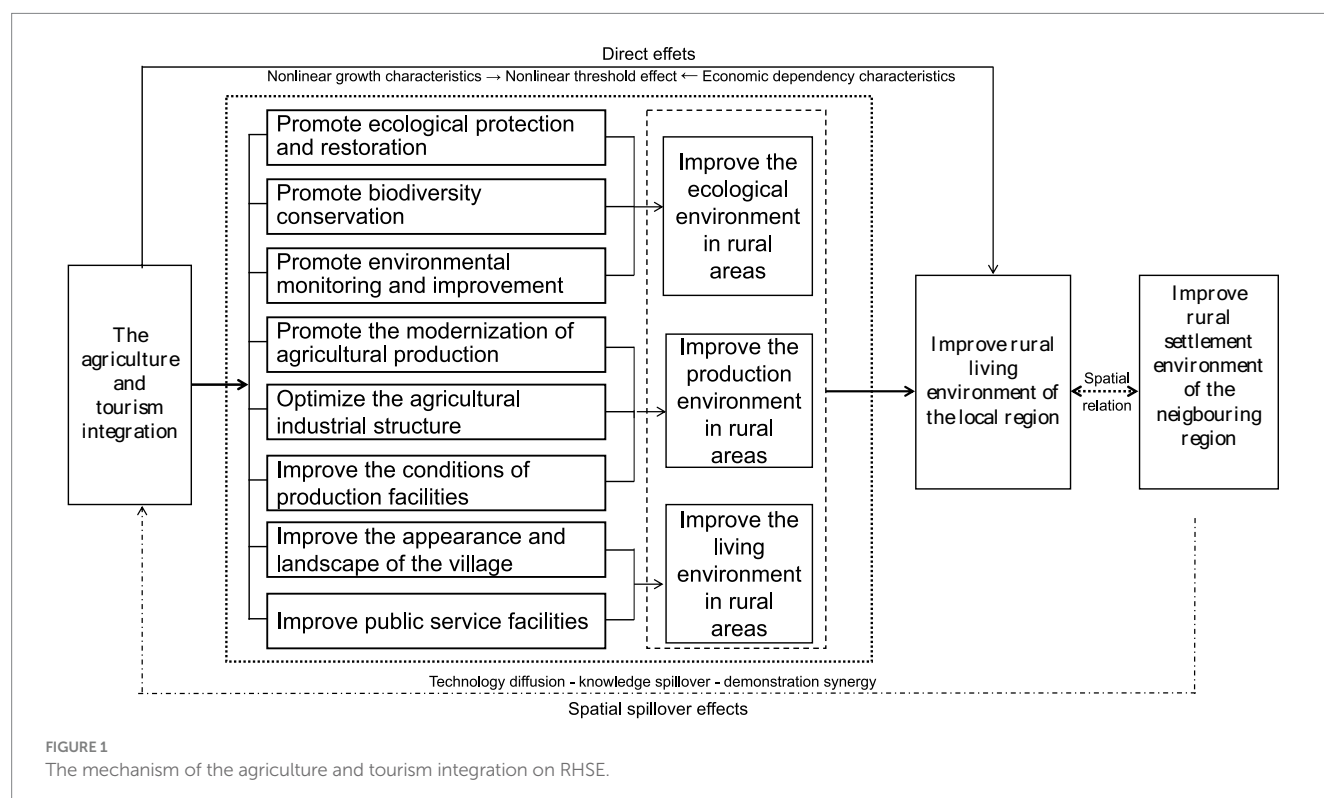
① Standardize the evaluation matrix:

If the evaluation indicators are positive indicators:

$$y_{ij} = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j};$$

If the evaluation indicators are negative indicators:

$$y_{ij} = \frac{x_{\max} - x_j}{\max x_j - \min x_j};$$



- ② Calculate the information entropy: $H_j = -k \sum_{i=1}^m p_{ij} \ln p_{ij}$
 (here $p_{ij} = \frac{y_{ij}}{\sum_{i=1}^m y_{ij}}$, $k = \frac{1}{\ln m}$);
 Define the weight of the j th indicator as: $W_j = \frac{1-H_j}{\sum_{j=1}^n (1-H_j)}$ (here $W_j \in [0,1]$ and $\sum_{j=1}^n W_j = 1$);

- ③ Construct the weight normalization matrix:

$$R = (r_{ij})_{m \times n}, r_{ij} = W_j \cdot y_{ij} \quad (i = 1, 2, \dots, n; j = 1, 2, \dots, m)$$

- ④ Determine the positive and negative ideal solutions S_j^+ and S_j^- respectively:

$$S_j^+ = \max(r_{1j}, r_{2j}, \dots, r_{nj})$$

$$S_j^- = \min(r_{1j}, r_{2j}, \dots, r_{nj})$$

- ⑤ Calculate the Euclidean distance:

$$d_i^+ = \sqrt{\sum_{j=1}^n (S_j^+ - r_{ij})^2}$$

$$d_i^- = \sqrt{\sum_{j=1}^n (S_j^- - r_{ij})^2}$$

- ⑥ Calculate the proximity degree LX_i :

$$LX_i = d_i^- / (d_i^- + d_i^+)$$

The proximity index LX_i represents the degree of closeness between the evaluated object and the positive ideal solution, which is the optimal solution, $LX_i \in (0,1)$. The value of LX_i gets closer to 1, indicating that the evaluated object is better, that is, the level of the evaluated object is higher, and vice versa.

3.2 Empirical model

3.2.1 Fixed effects model

3.2.1.1 Ordinary panel regression model

The fixed effects model can control individual unobserved factors that do not change over time, thus effectively addressing the bias problem caused by the omission of variables in the model (Halaby, 2004). Based on this, an individual fixed effects panel model was adopted to test the linear relationship between ATL and RHSE, which also was the benchmark model. The Equation (1) is set as follows:

$$RHSE_{it} = \alpha_0 + \beta_1 ATL_{it} + \sum_{k=1}^n \lambda_k Col_{it,k} + \mu_i + \nu_t + \xi_{it} \quad (1)$$

In model (1), $RHSE_{it}$ and ATL_{it} represent the explained variable and the core explanatory variable, respectively. The subscripts i and t indicate the province and the year, respectively. $Col_{it,k}$ is a set of control variables. μ_i and ν_t respectively represent the province and the time fixed effect, and ξ_{it} represents the random error term, which follows a normal distribution.

3.2.1.2 Dynamic panel regression model

Due to the significant influence of the previous period on RHSE (RHSE), in order to more objectively reveal the dynamic change process of RHSE, the lagged one-period RHSE of RHSE is introduced into model (1) to construct a dynamic panel econometric model as the following Equation (2):

$$RHSE_{it} = \alpha_0 + \tau RHSE_{i,t-1} + \beta_1 ATL_{it} + \sum_{k=1}^n \lambda_k Col_{it,k} + \mu_i + \nu_t + \xi_{it} \quad (2)$$

Due to the fact that the provincial heterogeneity characteristic μ_i may be correlated with other explanatory variables, the OLS estimation method will lead to the problem of omitted variable bias. Since the lagged first-period term of the explained variable is introduced as an explanatory variable in model (2), it may be correlated with the random disturbance term. Therefore, even if the fixed effect model is used to estimate and eliminate the individual effect μ_i , the endogeneity-induced parameter estimation bias cannot be eliminated. Arellano and Bond (1991) believed that when the endogenous variables in the model cause errors in the ordinary panel regression results, dynamic panel estimation can eliminate this error.

3.2.2 Spatial econometric model

3.2.2.1 Global Moran' I index

According to the first law of geography, regional economy is an open system. There are various material and non-material connections among different regions, which leads to mutual influence and interdependence among regions. The economic growth of a region no longer solely depends on its initial conditions, but also on the economic activities of surrounding regions (Mitchell, 2012). Therefore, when analyzing the impact of the integration of agriculture and tourism on the RHSE, if spatial factors are not considered, the results may be biased and even overestimate the impact. Whether to introduce spatial effects in the regression model depends on whether there is spatial correlation among economic variables. The spatial effect of economic variables can be tested by the Global Moran'I Index, which is defined as the following Equation (3):

$$Moran' I_{global} = \frac{\sum_{i=1}^n \sum_{j=1}^m W_{ij} (Y_i - \bar{Y})(Y_j - \bar{Y})}{S^2 \sum_{i=1}^n \sum_{j=1}^m W_{ij}} \quad (3)$$

In model (3), Y_i and Y_j , respectively, represent the observed values of ATL or RHSE in region i and region j . W_{ij} is the spatial weight matrix. The value range of the Moran' I index is between $[-1, 1]$.

When the index is greater than 0, it indicates that Y has positive spatial correlation. When the index is less than 0, it indicates the existence of negative spatial correlation. Otherwise, there is no spatial correlation.

3.2.2.2 Dynamic spatial Durbin model

The spatial models mainly include the spatial lag model (SLM) and the spatial error model (SEM) (Anselin, 1998). If both the explained variable and the explanatory variables exhibit spatial dependence, it is a spatial Durbin model (SDM). Given the spatial dependence of the explained variable RHSE and the explanatory variable ATL, this study constructed a spatial Durbin model. Since RHSE is also influenced by the previous stage's state, the lagged one-period term ($RHSE_{i,t-1}$) was added to the equation, which can effectively solve the endogeneity problem of the model. The dynamic spatial Durbin model is constructed as the following Equation (4):

$$RHSE_{it} = \alpha_0 + \tau RHSE_{i,t-1} + \rho \sum_{j=1}^n W_{ij} RHSE_{jt} + \beta X_{it} + \theta \sum_{j=1}^n W_{ij} X_{jt} + \mu_i + \nu_t + \xi_{it} \quad (4)$$

In model (4), $RHSE_{it}$ and X_{it} , respectively, represent the Explained variable and the explanatory variables (including control variables). The subscripts i and t indicate the province and the year, respectively. ρ is the spatial correlation coefficient, W_{ij} is the spatial weight matrix. τ , β , γ , and δ are the parameters to be estimated, u_i is the spatial effect, ν_t is the time effect, and ξ_{it} is the spatial error term. The spatial weight matrix includes the following two types: ① geographical distance spatial weight matrix ($W1$). It is usually calculated by the reciprocal of the square of the actual geographical distance between the two regions, that is $W_{ij} = 1/d_{ij}^2 (i \neq j)$. d_{ij} is represented by the direct distance between the two provincial capitals. $W1$ is selected as the benchmark spatial weight matrix. ② Economic geographical nested spatial weight matrix ($W2$), which is used for robustness analysis. It is calculated by the following formula: $W_{ij} = 1/|\bar{Y}_i - \bar{Y}_j + 1|e^{-d_{ij}} (i \neq j)$. $\bar{Y}_i$ and $\bar{Y}_j$ represent the Per capita GDP of i th and j th province. d_{ij} is also represented by the direct distance between the two provincial capitals. $W2$ is used for model robustness analysis.

3.2.3 Dynamic panel threshold model

As the level of agriculture tourism integration improves, more funds and technologies will be invested in rural infrastructure construction and ecological environment improvement, directly enhancing living conditions; at the same time, the deepening of integration will promote the optimization of rural industrial structure and facilitate the formation of green production and lifestyle, indirectly improving the quality of the living environment. Therefore, the impact of ATL on RHSE may have a non-linear relationship. Hence, this study uses the ATL as a threshold variable to test this non-linear relationship. Moreover, considering that RHSE has the characteristic of dynamic persistence, this study includes the $RHSE_{i,t-1}$ as an explanatory variable. Due to the lack of a mature method for combining spatial econometric models with threshold regression models at present, the following common dynamic panel threshold regression model is ultimately established as the following Equation (5).

$$RHSE_{it} = \alpha_0 + \tau RHSE_{i,t-1} + \beta_1 ATL_{it} \times I(ATL_{it} \leq \theta_1) + \beta_{12} ATL_{it} \times I(\theta_1 \leq ATL_{it} \leq \theta_2) + \dots + \beta_{1,n} ATL_{it} \times I(\theta_{n-1} \leq ATL_{it} \leq \theta_n) + \beta_{1,n+1} ATL_{it} \times I(ATL_{it} > \theta_n) + \sum_{k=1}^n \lambda_k C_{it,k} + \mu_i + \nu_t + \xi_{it} \quad (5)$$

In model (5), $\theta_1, \theta_2, \dots$ and θ_n are the threshold values, and there are $n+1$ threshold intervals, $\beta_{11}, \beta_{12}, \dots$, and $\beta_{1,n}$ are the regression coefficients under different threshold intervals. $I(\cdot)$ is the indicator function. $t-1$ represents the lag by one period, and other indicators are defined according to model (4).

3.3 Variable selection

3.3.1 Explained variable

In this study, rural human environment (RHSE) is taken as the Explained variable. Rural human environment refers to the conditions of the areas where farmers live together, and it is a spatial concept. Based on the research results of Liang et al. (2021), Bai and Wang (2019) and Deng et al. (2023), the rural human settlement environment is divided into three subsystems in this study and an evaluation index system is constructed to reasonably measure rural human settlement environment. Among them, the quality improvement of rural ecological environment is the foundation of rural human environment, and by protecting and restoring the natural ecosystem, biodiversity, and ecological landscape of the village, high-quality ecological background is provided for the sustainable development of the village. The improvement of rural production environment requires improving the rural industrial development mode, promoting environmental protection technologies, strengthening the green development of agriculture, forestry, animal husbandry, and fishery, as well as the ecological transformation of other rural industries such as agricultural product processing and rural tourism, in order to significantly reduce the negative impact of rural industrial activities on the environment and achieve green and low-carbon development of rural production space environment. The green development of RHSE requires improving the RHSE, increasing green facilities, and providing high-quality public services to enhance the quality of life and happiness of rural residents. In this regard, the evaluation index system for rural human settlement environment is constructed from three aspects: rural ecological environment (REE), rural production environment (RPE), and rural living environment (RLE) (as shown in Table 1). The entropy weight TOPSIS method was used to calculate the level of RHSE.

3.3.2 Explanatory variable and threshold variables

As mentioned above, the integration of agriculture and tourism occurs under the premise of the interconnection of the two industries. Therefore, the analysis of industry interconnection is the basis for evaluating the degree of industry integration. The new business forms formed by integration are the specific manifestations of industry integration, while the benefits of integrated development reflect the realization of the integration goals and represent the outcome state of the integration. Therefore, when measuring the level of agriculture tourism integration, the integration foundation conditions, integration manifestation forms, and integration benefit manifestations should be included in the evaluation framework. In view of this, referring to

TABLE 1 Evaluation index system of RHSE.

Primary indicators	Secondary indicators	Measuring indicators	Unit	Attribute
Rural ecological environment (REE)	Forest coverage rate	Forest coverage rate	%	+
	Per capita cultivated land area	Cultivated land area/rural population	Hectare per person	+
	Per capita water resources possession	Water resources possession/rural population	Cubic meters per person	+
	Nature reserve	The number of nature reserves	—	+
	Per capita afforestation area	The total area of afforestation in that year divided by the number of rural population	Square meters per person	+
		Key ecological engineering construction in forestry	Hectare	+
Rural production environment (RPE)	Fertilizer application intensity	Fertilizer application amount/total sown area of crops	Ton/hectare	+
	Intensity of pesticide use	Pesticide usage/total sown area of crops	Ton/hectare	+
	The intensity of agricultural film usage	The amount of agricultural film used/the total sown area of crops	Ton/hectare	+
	Crop damage rate	The area of crops affected by disasters/the total sown area of crops	%	+
Rural living environment (RHE)	The penetration rate of sanitary toilets	The number of households benefiting from toilet renovation divided by the total number of rural households	%	+
	The safety level of drinking water	The cumulative number of people who have benefited from water improvement/the total number of rural residents	%	+
	The coverage rate of rural tap water	Rural tap water beneficiary population/total rural population	%	+
	Total gas production per capita from biogas digesters	The total gas production of the biogas digester divided by the number of rural residents	Cubic meters per person	+
	Per capita solar water heater	Solar water heaters/rural population	Square meters per person	+

the approach of Wang et al. (2023), this paper constructs an index system for measuring the level of agriculture tourism integration and calculates it using the grey correlation degree model, factor analysis method, and entropy value method. Combining the research hypotheses in the previous text, in this paper, the level of agriculture tourism integration and regional economic development level (EGDP) are taken as threshold variables. The regional economic development level (EGDP) is measured by per capita GDP and is processed by taking the natural logarithm. All the indicators are shown in Table 2.

3.3.3 Control variables

This study selects the following control variables: ① Environmental Regulation (Enr), represented by the logarithmic form of the investment completed for industrial pollution control; ② Agricultural Industrial Structure (Str), measured by the proportion of the first industry's added value to the regional GDP; ③ Fiscal Support (Fis), measured by the proportion of local agricultural, forestry and water affairs expenditures to local general public budget expenditures; ④ Urbanization Level (Urb), measured by the proportion of urban population in the permanent resident population of each province; ⑤ Human Capital Level (Edu), represented by the average years of education, calculated according to the method of Wang et al. (2023).

3.4 Data sources and sample characteristics

This study conducts an empirical analysis using data from 30 provinces in China from 2008 to 2022. Due to data availability, Hong Kong, Macao, Taiwan, and Tibet were not included in the

research sample. The data mainly come from “China Rural Statistical Yearbook,” “China Statistical Yearbook,” “China Agricultural Yearbook,” “China Cultural and Tourism Statistical Yearbook,” “China Population and Employment Statistical Yearbook,” and “China Agricultural Product Trade Report.” Additionally, relevant data from the National Bureau of Statistics, the Ministry of Culture and Tourism, the Ministry of Agriculture and Rural Affairs, and provincial official websites are used as supplementary data sources. All data measured in monetary units are deflated using the 2008 base period, and quantitative analysis and model estimation are conducted using R language and GeoDa software. The descriptive statistics results of all variables are presented in Table 3.

3.5 Characteristics of RHSE and ATL in China

Based on the results of entropy weight TOPSIS calculation for RHSE, the average annual trend of RHSE in 30 provinces and four major regions of China from 2008 to 2022 is shown in Figure 2. Overall, from 2008 to 2022, China's RHSE showed an upward trend, with an average annual growth rate of 2.10%. This was mainly due to the fact that since the beginning of the new century, China has attached great importance to the improvement of rural human settlement environment, by continuously introducing action plans to promote policy implementation, focusing on the shortcomings of rural infrastructure and environmental problems, increasing resource investment, and at the same time establishing a governance model involving government, villagers, and social forces to promote

TABLE 2 Indicators of agriculture and tourism integration level.

Primary indicators	Secondary indicators	Measuring indicators	Attribute
Degree of industrial correlation	Gray correlation degree between agriculture and tourism industry X1	Regional added value of agriculture, domestic tourist visits, domestic tourism revenue	+
Demonstration effect	Integration of new business forms X2	National demonstration county for leisure agriculture and rural tourism, national key villages and towns for rural tourism, national quality park for leisure agriculture and rural tourism, national demonstration sites for leisure agriculture and rural tourism	+
Integration benefits	Investment X3	Orchard area, new fixed asset investment in agriculture, rural farmers' fixed asset investment	+
	Employment X4	Number of employees in rural individual businesses, number of employees in rural private enterprises	+
	Industrial development X5	Proportion of tourism revenue in GDP, proportion of agricultural output value in GDP	+

continuous improvement in rural hygiene conditions, environmental ecology, and village appearance. During the research period, the average annual growth rates of RHSE in the eastern, central, western, and northeastern regions were 2.01, 2.06, 2.31, and 2.08%, respectively. Among them, the growth rate of RHSE in the western region was higher than that of other regions, mainly because it is rural human settlement environment started from a relatively lower level and had a large potential for improvement. At the same time, the country implemented differentiated support policies for the western region, giving priority in areas such as ecological protection and infrastructure construction, in addition to the concentrated promotion of ecological restoration projects and rural human settlement improvement projects within the region, which jointly contributed to a higher growth rate.

Meanwhile, based on panel data, the grey correlation degree model, factor analysis method and entropy value method were used to measure the level of agriculture tourism integration (ATL). The results showed that the average level of agriculture tourism integration across the entire study area continuously increased over time (Figure 3), with an average annual growth rate of 8.06%. This was mainly due to China's recent efforts to promote rural industry integration, regarding agriculture tourism integration as an important focus for rural revitalization. Through policy guidance and resource support, it promoted the deep integration of agriculture and tourism. At the same time, with the upgrading of consumption, the demand for rural tourism continued to grow, driving the rapid development of agricultural tourism projects and promoting the overall integration level to improve. Among the four regions, the average level of agriculture tourism integration in the eastern region was the highest. This was mainly because it had a strong economic foundation, a mature tourism market, a close combination of agricultural resources and tourism elements, and was close to the main source of tourists. The industrial support was also complete, and a mature model and brand effect of agriculture tourism integration had been formed relatively early. The average annual growth rates of agriculture tourism integration in the eastern, central, western and northeastern regions were 7.93, 8.18, 7.20 and 7.73%, respectively. Among them, the growth rate of agriculture tourism integration in the central region was higher than that of other regions. This was mainly because the central region had

abundant agricultural resources and distinctive characteristics, and had natural advantages for developing agriculture tourism integration; on the other hand, in recent years, the central region relied on policy support to strengthen infrastructure construction such as transportation, actively bare industrial transfer, and at the same time, based on regional characteristics, it created agricultural tourism projects, achieving rapid growth from a relatively low starting point.

4 Results

To avoid potential errors caused by a single test, this study first uses three methods—IPS, LLC, and ADF-Fisher—to conduct unit root tests on the data (Im et al., 2003). The results show that all variables reject the null hypothesis of the existence of a unit root, indicating that the panel data has good stationarity and can be used for panel regression analysis.

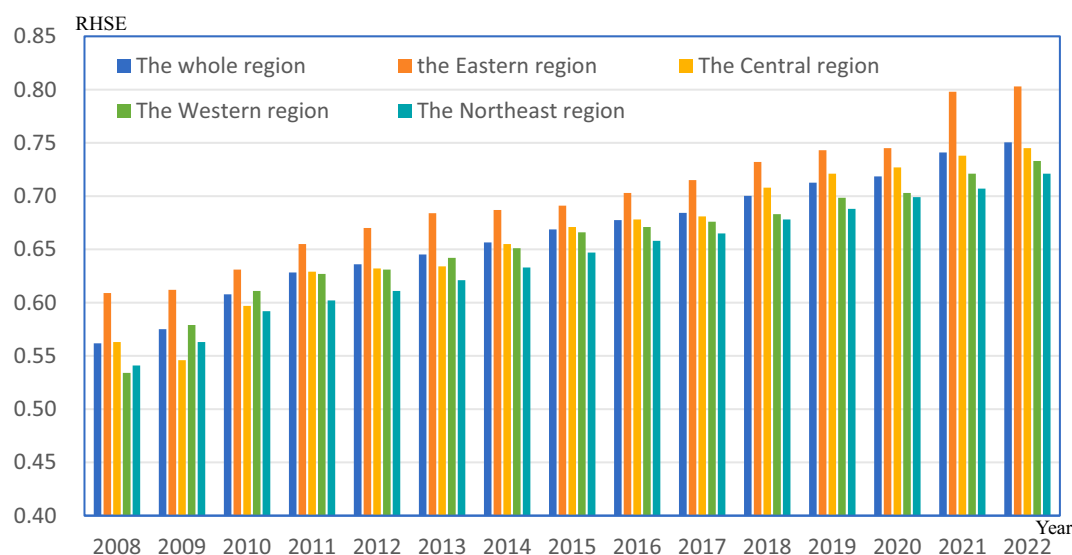
4.1 Results of fixed effects estimation

4.1.1 Results of full sample estimation

To test the impact effect of the level of agriculture tourism integration on RHSE and its three dimensions—rural ecological environment, rural production environment, and rural living environment, ordinary panel fixed effects models and dynamic panel fixed effects models were constructed for estimation. Firstly, through *F*-test, it was found that the individual fixed effects were significant. Additionally, the Hausman test rejected the null hypothesis that there were no systematic differences in the coefficients of random effects (RE) and fixed effects (FE). Therefore, the individual fixed effects model can be given priority. From the estimation results of the ordinary panel individual fixed effects model, it can be seen that agriculture tourism integration has a significant positive impact on RHSE at the 1% significant level. The regression coefficient is 0.364, indicating that under the condition that other factors remain unchanged, for every 1-unit increase in the level of agriculture tourism integration, the level of RHSE will increase by 0.364 units.

TABLE 3 Descriptive statistical results of variables.

Variable	Observations	Mean	Med.	Stv.	Max	Min
RHSE	450	0.665	0.652	0.217	0.842	0.348
REE	450	0.676	0.659	0.189	0.842	0.351
RPE	450	0.624	0.618	0.132	0.808	0.348
RHE	450	0.647	0.642	0.205	0.870	0.381
ATL	450	0.877	0.845	0.339	2.134	0.253
Enr	450	11.183	12.643	1.654	2.874	14.287
Str	450	0.131	0.128	0.097	0.367	0.071
Urb	450	0.551	0.542	0.136	0.897	0.211
Fis	450	0.112	0.104	0.061	0.172	0.081
Edu	450	7.432	7.521	0.932	9.012	3.454
EGDP	450	9.333	0.930	2.532	11.101	6.511

FIGURE 2
The development trend of RHSE in China from 2008 to 2022.

In order to capture the “inertia” of the development of RHSE, the lagged first-period term of the RHSE level was included in the estimation model. This lagged first-period term may be correlated with the random error term, leading to endogeneity problems in the model and resulting in deviations in the regression results. To overcome endogeneity, considering the “large N small T” feature of the panel data structure used in this study, it is more appropriate to use SYS-GMM to estimate the dynamic panel model. According to the estimation results of the dynamic panel model in model (2), the lagged first-period term of RHSE is positively correlated with the current RHSE level ($p < 0.01$). For every 1 unit increase in the previous RHSE level, its level in the current period will increase by 0.321. This indicates that there is a certain dynamic inertia in the RHSE level. In addition, the regression coefficient of agriculture tourism integration is 0.347 ($p < 0.01$), which is slightly lower than that of the ordinary panel fixed effect model.

From the results of model (8)–(13) in Table 4, it can be seen that the integration of agriculture and tourism has a significant positive impact on all the sub-dimensions of RHSE. Hypotheses 1a, 1b, and 1c

have been confirmed. Based on the estimation of the dynamic panel regression model, the integration of agriculture and tourism has a significant positive impact on rural ecological environment and rural living environment. For every 1-unit increase in the level of agriculture tourism integration, the levels of rural ecological environment, rural production environment, and rural living environment increase by approximately 0.195, 0.117, and 0.431 unit, respectively. From the above regression coefficients, the impact of agriculture tourism integration on the rural living environment dimension is more prominent, while the impact on the rural production environment dimension is relatively weak.

In terms of controlling variables, the agricultural industrial structure has a negative impact on the RHSE. Other control variables have positive impacts on the RHSE: ① Environmental regulation (Enr) has a positive impact on the level of RHSE. Increasing the intensity of environmental regulation can directly restrain enterprises’ pollution behavior, reducing the pollution of wastewater, waste gas, and solid waste to the rural soil, water sources, and air. At the same time,

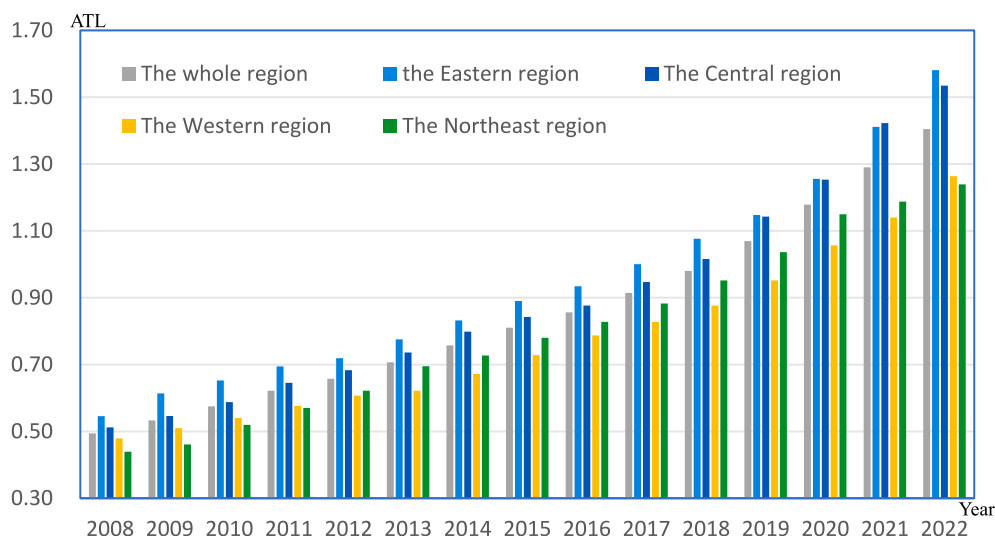


FIGURE 3
The development trend of ATL in China from 2008 to 2022.

TABLE 4 Estimation Results of the whole research region.

Variables	Explained variable—RHSE		Explained variable—REE		Explained variable—RPE		Explained variable—RHE	
	FE model (6)	SYS-GMM model (7)	FE model (8)	SYS-GMM model (9)	FE model (10)	SYS-GMM model (11)	FE model (12)	SYS-GMM model (13)
ATL_{it}	0.376*** (4.022)	0.347*** (4.298)	0.210*** (6.021)	0.195*** (4.013)	0.262** (4.002)	0.117*** (3.801)	0.462** (3.012)	0.431*** (7.005)
Enr_{it}	0.154** (3.112)	0.102** (3.041)	0.165* (2.054)	0.128* (2.002)	0.281* (2.106)	0.213* (2.232)	0.281* (2.236)	0.184* (1.972)
Str_{it}	−0.028* (−2.021)	−0.019* (−1.964)	−0.043** (−3.017)	−0.038 (−0.803)	−0.023 (−0.915)	−0.012 (−0.015)	−0.021 (−0.002)	−0.032 (−0.015)
Urb_{it}	0.052* (2.041)	0.026* (2.007)	0.061** (2.321)	0.045** (3.014)	0.014* (2.111)	0.011* (1.961)	0.038* (2.210)	0.022* (2.101)
Fis_{it}	0.121* (2.033)	0.151* (2.001)	0.017** (3.012)	0.261* (2.031)	0.135* (2.415)	0.061* (2.322)	0.035* (2.016)	0.021* (2.221)
EDU_{it}	0.187* (2.047)	0.169** (2.846)	0.224* (2.214)	0.132* (0.096)	0.116* (2.142)	0.076** (3.081)	0.528* (2.031)	0.487* (2.165)
Explained variable lagged by one period.		0.321*** (4.011)		0.223*** (5.131)		0.398*** (4.024)		0.311*** (7.018)
F_test	26.831***		28.754***		16.936**		22.340**	
Hausman_test	28.983***		32.831***		24.398***		31.651*** 0.8132	
R^2	0.7865		0.7011		0.6865			
AR (1) test		−3.925*** [0.000]		−2.525*** [0.000]		−4.084*** [0.000]		−3.544*** [0.000]
AR (2) test		1.154 [0.298]		0.896 [0.174]		1.376 [0.486]		1.876 [0.415]
Hansen_test		21.877 [0.094]		32.021 [0.143]		17.907 [0.286]		23.547 [0.136]

***, **, and * Indicate significance at the 1%, 5%, and 10% levels, respectively. The values within square brackets are robust standard errors, and those within parentheses are *T*-values.

regulatory pressure will force enterprises to adopt clean production technologies, indirectly reducing the environmental risks of agricultural production, thereby improving the quality of RHSE; ②

Fiscal support (Fis) has a positive impact on the RHSE. An increase in the proportion of local agricultural, forestry, and water affairs expenditures means an increase in the government's investment in

rural infrastructure, ecological restoration, and agricultural green subsidies. These funds are directly used for environmental improvement projects, which can effectively enhance the level of rural public services and human settle environment; ③ Urbanization level (Urb) has a positive impact on the RHSE. The urbanization process involves the concentration of population in urban areas, reducing the density of rural population and thereby reducing the pressure of resource consumption and waste emissions. At the same time, advanced environmental governance technologies, management experience, and public service models in urban areas may spread to rural areas through the “radiation effect,” promoting the upgrading of RHSE facilities. In addition, urbanization can promote rural land transfer and large-scale operations, reducing the negative externalities of scattered livestock breeding and small-scale farming, and further weakening the ecological carrying capacity of rural areas, having a negative impact on the living environment (Sepahvand et al., 2021); ④ Human capital level (Edu) has a positive impact on the RHSE. An increase in the years of education of residents will enhance their environmental protection awareness and participation willingness, more inclined to adopt green lifestyles (such as reducing the use of disposable items, actively participating in garbage classification), and forming social supervision pressure on polluting behaviors. At the same time, the high human capital group is more likely to accept ecological agricultural technologies (such as soil testing and fertilization), promoting the transformation of agricultural production methods, and indirectly reducing the damage to the rural environment (Deng et al., 2023); ⑤ the agricultural industrial structure has a negative impact on the level of RHSE. The higher the proportion of the first industry’s added value, the more dominant agriculture is in the economy. Excessive use of fertilizers and pesticides in traditional agricultural production can easily cause non-point source pollution, and improper treatment of livestock breeding waste can also exacerbate environmental pressure. In addition, a single agricultural structure may lead to excessive land exploitation and a decline in ecological diversity, further weakening the ecological carrying capacity of rural areas, having a negative impact on the living environment (Yu F. et al., 2022).

4.1.2 Results of endogeneity and robustness test

- (1) Use the instrumental variable method (model 14). The integration of agriculture and tourism promotes the improvement of RHSE, and at the same time, the improvement of RHSE may also promote the integration of agriculture and tourism. The two may be mutually causal, so the endogeneity issue needs to be addressed. This study follows the approach of Zhong et al. (2020), selects the density of the road network as a tool variable is mainly based on two reasons: Firstly, the intensity of government support for the integration of agriculture and tourism can be reflected in the construction of transportation infrastructure. For the development of the integration of agriculture and tourism, the transportation infrastructure must be well constructed, so the level of the integration of agriculture and tourism can be represented to some extent by the density of the road network; secondly, the road network density does not directly affect the rural living environment. The results of the first-stage regression show that the F-statistic value is greater than 10 and passes the 5% significance test, indicating that there is no problem of weak

instrument variable. The coefficient of the integration level in the second stage is still positive and significant (shown in Table 5), indicating that the integration of agriculture and tourism has a positive promoting effect on the rural living environment.

- (2) Obtain robust standard errors through the bootstrap method (model 15). Panel data usually assumes that the disturbance terms of different individuals are independent, and there is no autocorrelation between the disturbance terms of the same individual and the same period. Considering heteroscedasticity and autocorrelation, in small samples, the cluster robust standard errors at the provincial level are not accurate enough, while the bootstrap method can obtain more accurate results. Therefore, this study replaces the cluster robust standard errors with bootstrap standard errors. In the calculation process, the Bootstrap number is set to 500 times.
- (3) Change the sample size (model 16). Generally, municipalities directly under the Central Government enjoy greater national policy inclination and stronger autonomy. In this context, municipalities can improve the decision-making speed in economic construction and promote infrastructure renewal and improvement of living environment governance in a targeted manner. From the perspective of economic development, the four municipalities have fully exerted their economic radiation and formed three important economic growth poles in the Beijing-Tianjin-Hebei, Yangtze River Delta, and Chengdu-Chongqing regions. Therefore, the samples of these four cities were removed, and then a fixed dynamic panel model estimation was conducted.
- (4) Change the research period (model 17). After the implementation of the rural revitalization strategy, the national and local governments implemented a series of policies to promote RHSE governance. In this case, the regression was conducted using the samples from 2010 to 2017 to exclude the interference of a series of policies implemented after the implementation of the rural revitalization strategy on the empirical results. The regression results are shown in Table 5.

From the regression results in Table 5, it can be seen that in all the models, the relationship between the core explanatory variable ATL and RHSE has remained unchanged in all four models, and the significance of these models has also remain unchanged. Therefore, it can be determined that the benchmark regression results are robust and the conclusion is reliable.

TABLE 5 Results of endogeneity and robustness tests.

Variables	Model 14	Model 15	Model 16	Model 17
ATL	0.226*** (3.596)	0.546*** (4.091)	0.417** (2.917)	0.396*** (3.323)
Controlling variables	Controlled	Controlled	Controlled	Controlled
Observations	450	450	338	240

*** Indicates significance at the 1% confidence level.

4.2 Results of spatial panel model estimation

4.2.1 Results of global spatial autocorrelation test

After calculation, the global Moran's I values of ATL and RHSE in China for each year from 2008 to 2022 were all significantly positive (Table 6), indicating that ATL and RHSE have significant spatial correlation. From the temporal perspective, the mean values of the global Moran's I of ATL and RHSE generally showed an increasing trend year by year. Although they decreased slightly from 2020 to 2022 due to the impact of the epidemic, there is still significant spatial correlation. Thus, it can be seen that the spatial clustering trend of ATL and RHSE has been continuously strengthening.

4.2.2 Results of spatial econometric model estimation

Through the above spatial autocorrelation tests, it can be seen that both RHSE and ATL have strong spatial correlation characteristics. Therefore, when studying the relationship between the two, spatial factors should be taken into consideration. After the tests, the test statistics of LM-lag, Robust LM-lag, LM-error, and Robust LM-error all passed the significance test, indicating that the null hypothesis could be rejected, that is, the spatial panel model is applicable. However, in combination with the Wald and LR statistics, it is necessary to determine which spatial model is more appropriate. Estimating based on the spatial Durbin model as the benchmark shows that both the Wald and LR statistics passed the significance test, indicating that using the spatial Durbin model to fit the data is more appropriate. All tests used the geographical distance spatial weight matrix. In the two types of spatial Durbin models, the Hausman test rejected the null hypothesis ($p < 0.01$), so the fixed effect model is more appropriate. At the same time, to avoid the influence of unobserved time changes on the estimation results, the bidirectional fixed Durbin model was finally selected for empirical analysis.

Based on two types of spatial weight matrices for model estimation, the impact coefficients of ATL on RHSE in all models are positive and have passed the significance test (as shown in Table 7). From the perspective of model fit goodness R^2 , the dynamic spatial Durbin model has a higher fit goodness than the static spatial Durbin model, indicating that the dynamic spatial Durbin model is more ideal. Additionally, the dynamic spatial Durbin model based

on the geographical distance weight matrix has the highest fitting degree, so the subsequent analysis mainly focuses on the results of model 20 in Table 7. The ATL coefficient in the estimation results of model 20 is 0.236 ($p < 0.01$), which is lower than the estimated coefficient of the static spatial Durbin model, indicating that the static model overestimated the positive effect of ATL on RHSE. The coefficient of the spatial lag term of ATL (W^*ATL) is significantly positive at the 5% confidence level, indicating that there is an interaction between ATL across provinces, and the local ATL will affect the RHSE of adjacent provinces. In conclusion, the impact of ATL on RHSE has spatial spillover effects, and the research hypothesis 2 is verified.

Due to the spatial spillover effect of ATL, the above regression coefficients of ATL cannot directly explain its marginal effect on RHSE. Therefore, it is necessary to decompose them to better reveal the direct effect (local effect) and indirect effect (spatial spillover effect) of ATL on RHSE. The decomposition results are shown in Table 8: Under the global sample, the regression coefficient of the direct effect of ATL on RHSE is 0.156 ($p < 0.05$), and the regression coefficient of the spillover effect is 0.108 ($p < 0.1$), indicating that the increase in ATL in this region can promote the increase in RHSE in this region and its surrounding areas.

4.2.3 Regional heterogeneity analysis

Given the significant differences in the development of agriculture and tourism between different regions in China, this study follows the approach of Deng et al. (2023) and divides the entire study area into four regions: the eastern, central, western, and northeastern regions for model estimation, in order to test the heterogeneity among regions (Table 9). The results show that the estimated results of each region are basically consistent with the estimated results of the entire sample: the direct impact of ATL on RHSE and the spatial spillover effect are both significant, indicating that the above research results are relatively robust. The coefficients of $RHSE_{it-1}$ in all four regions are significantly positive, and all regions' RHSE are affected by the previous stage's state; and the spatial autocorrelation coefficients ρ are all significantly positive, indicating that RHSE has a spatial spillover effect. In addition, the coefficients of W^*ATL_{it} in the eastern, central, and western regions are all significantly positive. The ATL in this

TABLE 6 Global Moran' I values of ATL and RHSE from 2008 to 2022.

Global Moran' I values of ATL						Global Moran' I values of RHSE					
Year	Moran' I values	p values	Year	Moran' I values	p values	Year	Moran' I values	p values	Year	Moran' I values	p values
2008	0.234**	0.003	2016	0.276**	0.028	2008	0.328*	0.078	2016	0.412*	0.054
2009	0.239***	0.004	2017	0.269**	0.013	2009	0.335*	0.019	2017	0.410**	0.019
2010	0.243*	0.005	2018	0.284***	0.004	2010	0.339*	0.096	2018	0.420***	0.006
2011	0.247*	0.003	2019	0.283**	0.028	2011	0.367**	0.045	2019	0.457**	0.013
2012	0.256**	0.013	2020	0.213**	0.019	2012	0.374**	0.021	2020	0.443**	0.026
2013	0.257***	0.004	2021	0.221***	0.006	2013	0.369**	0.044	2021	0.417***	0.007
2014	0.269**	0.021	2022	0.214***	0.003	2014	0.387*	0.071	2022	0.420**	0.015
2015	0.273**	0.032				2015	0.400**	0.043			

*, **, *** Indicate significance at the 10%, 5%, and 1% confidence levels, respectively.

TABLE 7 Estimation results of spatial Durbin model.

Variable	Static space Durbin model		Dynamic space Durbin model	
	Model 18 (W1)	Model 19 (W2)	Model 20 (W1)	Model 21 (W2)
RHSE _{it-1}			0.315*** (3.376)	0.268** (2.768)
ATL _{it}	0.335** (2.997)	0.311*** (4.315)	0.248*** (3.752)	0.199*** (4.432)
Enr _{it}	0.145*** (3.186)	0.119*** (4.191)	0.176*** (4.966)	0.106** (3.221)
Str _{it}	−0.019*** (−4.969)	−0.078*** (−4.139)	−0.017*** (−2.118)	−0.011*** (−4.127)
Urb _{it}	0.031*** (3.326)	0.063** (3.131)	0.059** (2.675)	0.043*** (5.032)
Fis _{it}	0.121* (4.081)	0.143* (3.241)	0.137** (2.695)	0.210** (3.765)
Edu _{it}	0.186* (2.421)	0.161** (2.822)	0.194* (2.323)	0.162** (2.965)
W*ATL _{it}	0.175** (3.097)	0.098** (2.135)	0.124** (2.723)	0.132** (3.031)
Adj R ²	0.811	0.754	0.826	0.732
ρ	0.451*** (3.231)	0.432*** (4.635)	0.274*** (3.819)	0.255*** (4.132)
Log L	116.324	122.875	145.543	128.326

TABLE 8 Results of spatial effect decomposition.

Variables	ATL _{it}	Enr _{it}	Urb _{it}	Str _{it}	Fis _{it}	EDU _{it}
Direct effect	0.156*** (4.110)	0.112* (2.316)	0.106** (3.026)	−0.015** (−2.664)	0.198** (3.208)	0.112** (2.681)
Spillover effect	0.108** (2.987)	0.101* (2.027)	−0.015** (−2.568)	−0.056* (−2.217)	−0.023* (−2.295)	0.075** (2.352)
Total effect	0.264** (2.641)	0.213* (2.315)	0.091* (2.315)	−0.071* (−1.987)	0.174* (2.109)	0.187** (2.654)

*, **, *** Indicate significance at the 10%, 5%, and 1% confidence levels, respectively.

TABLE 9 Estimation results by region.

Variables	Eastern region	Central region	Western region	Northeastern region
ATL _{it}	0.278** (2.876)	0.324** (3.153)	0.197** (3.156)	0.165** (2.746)
Enr _{it}	0.158* (2.084)	0.131* (1.995)	0.225* (2.356)	0.201* (1.999)
Str _{it}	−0.108* (−1.997)	−0.034* (−2.068)	−0.076* (−2.175)	−0.025* (−2.168)
Urb _{it}	0.343** (3.121)	0.176** (3.086)	0.178 (1.608)	0.221* (2.166)
Fis _{it}	0.176* (2.087)	0.215** (3.243)	0.321** (3.154)	0.118** (3.141)
Edu _{it}	0.313* (2.543)	0.265** (3.074)	0.188 (1.743)	0.132** (3.115)
W*ATL _{it}	0.209* (2.614)	0.115** (2.875)	0.101** (2.765)	0.087* (1.964)
Adj R ²	0.8518	0.8273	0.7164	0.7815
ρ	0.221** (2.787)	0.207** (2.608)	0.198** (2.765)	0.171** (2.632)
Log L	148.084	176.351	111.843	78.549

*, **, *** indicate significance at the 10%, 5%, and 1% confidence levels, respectively.

region has a positive spatial spillover effect on the RHSE of surrounding regions, but the spillover effect is not significant in the northeastern region.

Furthermore, this study decomposes the spatial effects of different regions. The results are shown in Table 10: in terms of direct effects, the direct effect of the central region is the strongest, with a coefficient of 0.307 ($p < 0.05$). This might be because the resource foundation for agriculture tourism integration in the central region is better, while the RHSE is not high. Therefore, the marginal enhancing effects such as technological penetration brought by agriculture tourism integration are more significant. In terms of spatial spillover effects, the spillover effect coefficient of ATL in the eastern region on the improvement of RHSE is 0.101 ($p < 0.05$), which is greater than the coefficient of other regions.

However, the spillover effect in the northeastern region is not significant.

4.3 Threshold effect test results and analysis

To demonstrate whether there is a non-linear characteristic in the impact of agriculture tourism integration on RHSE, a threshold effect regression model is employed for the test. The first step in the threshold effect regression model test is to determine the threshold value and the number of threshold variable components (Pan et al., 2024). For this purpose, ATL is used as the threshold variable. In the single threshold and double threshold tests, the F -statistics passed the

TABLE 10 Spatial effect analysis of different regions.

Variables	Eastern region	Central region	Western region	Northeastern region
Direct effect	0.216*** (3.975)	0.307*** (5.614)	0.137** (2.591)	0.121** (3.097)
Spillover effect	0.101** (3.143)	0.076** (3.114)	0.075** (2.605)	0.012 (1.448)
Total effect	0.321** (2.986)	0.383** (2.978)	0.212** (2.813)	0.133** (1.987)

*, **, *** Indicate significance at the 10%, 5%, and 1% confidence levels, respectively.

significance level test, and all null hypotheses were rejected. However, in the triple threshold effect test, the *F*-statistic did not pass the significance level test, and the null hypothesis could not be rejected. Thus, a “double threshold” effect can be concluded. When the economic development level (EGDP) is used as the threshold variable, the test process for the threshold value and the number of threshold variables is similar to the previous one. After the test, it is found that EGDP has a single threshold and no multiple thresholds (see Table 11).

Since the threshold regression model contains the lagged term of the explained variable, using ordinary least squares (OLS) for estimation would lead to biased parameters. Therefore, this study uses the system generalized method of moments estimation method for estimation, and the estimation results are shown in Table 12.

When ATL is used as the threshold variable, the regression coefficient of ATL is always positive and significant for the entire study area, fully demonstrating that the integration of agriculture and tourism is conducive to the improvement of RHSE. However, the regression coefficient of ATL varies in different intervals. When ATL is in the first interval ($ATL \leq 0.985$), its regression coefficient is 0.257 ($p < 0.05$); when ATL is in the second interval ($0.985 < ATL \leq 1.397$), its regression coefficient decreases to 0.165 ($p < 0.1$); when ATL enters the third interval ($ATL > 1.397$), it is regression coefficient rises to 0.404 ($p < 0.05$).

When using EGDP as the threshold value, the model estimation results show that: when EGDP is below the threshold of 0.921, the regression coefficient of ATL on RHSE is 0.225 ($p < 0.05$); when EGDP is above the threshold of 0.921, the regression coefficient of ATL on RHSE is 0.431 ($p < 0.01$). Thus, it can be concluded that as the economic development level rises, the influence effect of ATL on RHSE shows an increasing trend. Therefore, Research Hypothesis 3 is verified.

5 Discussion

5.1 Direct effects of ATL on RHSE

The estimation results of both the ordinary panel fixed-effect model and the dynamic panel fixed-effect model indicate that agriculture tourism integration exerts a significant positive impact on the rural living environment. Specifically, in the dynamic panel fixed-effect model, the regression coefficient of agriculture tourism integration stands at 0.347 ($p < 0.01$), which is slightly lower than that in the ordinary panel fixed-effect model. This is primarily because, in the dynamic panel model, the development of the rural living environment exhibits a certain “inertia”—the one-period lagged rural living environment level has already accounted for part of the variation in the current level. In contrast, the ordinary fixed-effect model, which does not incorporate the lag term, may “attribute” some

of the effects arising from the inertia of the previous rural living environment development to agriculture tourism integration, thereby leading to an overestimated regression coefficient.

In terms of the regression coefficients of agriculture tourism integration on different dimensions of RHSE, its impact is more pronounced on the dimension of rural living environment, while relatively weaker on the dimension of rural production environment. This could be attributed to the fact that the direct demand of agriculture tourism integration drives the priority improvement of the living environment. To attract tourists, the improvement of the rural living environment has become a fundamental task, and various regions tend to develop villages into rural tourism attractions, directly enhancing the quality of the living environment. However, the improvement of the agricultural production environment is constrained by multiple practical bottlenecks. Currently, rural areas are confronted with issues such as an imbalanced labor structure, fragmented landholdings, and a low level of agricultural technology, meaning that upgrading the production environment requires long-term investment. In the initial stage of agriculture tourism integration projects, the focus is more on supporting facilities related to tourism experience, with limited support for technological upgrading in agricultural production links and the optimization of land transfer mechanisms. Moreover, small-scale farmers face challenges like high costs of scientific and technological investment and high technical thresholds (Newell et al., 2009; Joo et al., 2013), making it difficult to achieve rapid and substantial improvements in the production environment.

5.2 Spatial spillover effects of ATL on RHSE

From the estimation results of the Spatial Durbin Model, the increase in local agriculture tourism integration (ATL) can promote the improvement of the rural human settlement environment (RHSE) in both the local and surrounding areas under the full sample. The main reasons may be as follows: On the one hand, with the further improvement of agricultural tourism and leisure infrastructure in various regions, the locations of pioneering ATL projects driven by innovative development and differentiated management will first gain tourists' favor, attracting more tourists from local and surrounding areas in the short term, thereby creating regional competitive pressure. To gain an advantage in competition, surrounding areas will also utilize or integrate local agricultural resources, create innovative and unique business models, and develop attractive ATL experience products. It can be seen that ATL in one region can not only directly drive the adjustment of rural industries in that region but also promote agricultural innovative development in surrounding areas. On the other hand, with the improvement of the efficiency of transportation, logistics, and information interaction, the level of inter-regional

TABLE 11 Threshold characteristics test.

Threshold variable	Model test	Threshold estimate	<i>F</i> statistic	<i>p</i> value	Critical values		
					1%	5%	10%
ATL	Single threshold	0.985	21.548***	0.003	14.097	6.865	4.432
	Double threshold	Threshold 1:0.985 Threshold 2:1.397	14.237**	0.028	21.943	14.843	10.132
	Triple threshold	—	2.221	0.170	5.909	2.558	1.029
EGDP	Single threshold	0.931	39.098***	0.000	11.975	6.843	3.987
	Double threshold	—	2.019	0.498	3.114	2.764	1.498

*, **, *** Indicate significance at the 10%, 5%, and 1% confidence levels, respectively.

TABLE 12 Estimation results of dynamic threshold effect.

Threshold variable	Threshold and interval	Regression coefficient	<i>T</i> -value	Standard error
ATL	The first interval: $ATL \leq 0.985$	0.257**	3.051	0.002
	The second interval: $0.985 < ATL \leq 1.397$	0.165*	2.132	0.001
	The third interval: $ATL > 1.347$	0.405**	2.943	0.051
EGDP	The first interval: $EGDP \leq 0.921$	0.225**	2.654	0.032
	The second interval: $EGDP > 0.921$	0.431***	4.765	0.007

*, **, *** Indicate significance at the 10%, 5%, and 1% confidence levels, respectively.

cooperative development and collaborative governance has been enhanced, which has created favorable conditions for the formation of spatial spillover effects of ATL. Therefore, ATL not only promotes the upgrading of the local agricultural structure and the transformation of development patterns but also drives the optimization of agricultural labor allocation and agricultural industrial structure in surrounding areas, helping to improve the quality of agricultural development in surrounding areas and promote the rise of RHSE in those areas. Meanwhile, it is worth noting that although the regression coefficient of the spillover effect of ATL passed the significance test, the significance level was $p < 5\%$, while the significance level of the direct effect regression coefficient was $p < 0.01$, which is consistent with Lupi's research conclusions. A possible reason is that the current market for ATL leisure products is characterized by intense competition and widespread homogeneous product competition, leading to consumers experiencing aesthetic fatigue and poor perceived experience, which limits the spatial spillover effects of ATL (Wang et al., 2023).

The decomposition results of spatial effects across different regions show that: in terms of direct effects, the central region has the strongest direct effect. This may be because the central region has a solid resource foundation for ATL, while the RHSE level is not high; thus, the marginal improvement effects such as technological penetration brought by ATL are more significant. In terms of spatial spillover effects, the eastern region has a stronger spillover effect than other regions. This may be attributed to the following: relying on high-efficiency agriculture and urban tourism demand, the eastern region has formed industrial clusters such as sightseeing agriculture and rural complexes, and promotes the diffusion of environmental governance experiences to neighboring areas through regional tourism alliances and transportation networks. At the same time, industrial and commercial capital investment and smart agricultural technologies spill over through cross-regional investment or training, driving the

improvement of hardware and management levels of the rural human settlement environment in surrounding areas. In contrast, the spillover effect in the northeastern region is not significant, mainly due to the following: most ATL projects in the northeastern region rely on traditional planting, resulting in homogeneous industrial formats and a short peak season affected by the long winter, making it difficult to form a sustained tourist flow driver; the lack of regional collaboration mechanisms, the disconnection between agricultural scale and tourism supporting facilities, and resource competition among regions outweighing cooperation, which makes it difficult to share environmental improvement experiences across regions according to Zhang et al. (2011).

5.3 Threshold effects of ATL on RHSE

The estimation results of the threshold effect show that the impact of agriculture tourism integration (ATL) on the rural human settlement environment (RHSE) presents a trend of first strengthening, then weakening, and then strengthening again as the level of ATL improves. The possible reasons for this result are as follows: In the initial stage of ATL, the low-level integration of agriculture and tourism rapidly achieves the “hardware improvement” of RHSE through infrastructure sharing and recombination of production factors. This stage is dominated by projects to make up for weaknesses such as road hardening and sanitation facility renovation, with the dividends of environmental effects released intensively, and ATL shows a significant promoting effect on RHSE. As integration deepens, when the intensity of tourism development exceeds the ecological carrying threshold, ecological pressures such as a surge in domestic waste and soil damage caused by farmland commercialization emerge; meanwhile, the cost of interest coordination among farmers, enterprises, and

the government rises (Zhong et al., 2020). The marginal returns of the integration of primary factors diminish, technological innovation has not yet made breakthroughs, and the role of ATL in RHSE enters a “plateau period,” with the impact effect decreasing. After the integration level breaks through the threshold value of 1.347, circular agriculture technology diffuses through tourism scenarios, and the premium of eco-tourism brands promotes long-term governance investment in intelligent monitoring and ecological compensation. The overlap of scale effect and technology spillover effect leads to a significant rise in the promoting effect of ATL on RHSE, marking that the integration has entered a high-quality stage of “environment-economy” synergy.

Additionally, with the rising economic development level, the impact effect of ATL on RHSE shows an increasing trend. The main reasons may be as follows: When the regional economic development level is low, factors such as weak infrastructure and insufficient technological reserves restrict the exertion of the effect of optimizing factor allocation in ATL, and only a small improvement in RHSE can be achieved through the linkage of primary business formats (Gao et al., 2014; Ayyildiz and Koc, 2024). When EGDP crosses the threshold value, improved market mechanisms, penetration of digital technology, and diffusion of green innovation can form synergistic support, enabling the synergistic effect of factor recombination and technological innovation in ATL to be fully exerted, thereby significantly strengthening its role in improving RHSE.

6 Conclusions and policy recommendations

6.1 Conclusion

Based on panel data of 30 provinces in China from 2008 to 2022, this study empirically examines the impact of agriculture tourism integration on RHSE using fixed effect models, spatial Durbin models, and threshold effect models. The main conclusions are as follows: ① both the levels of RHSE and agriculture tourism integration exhibit significant spatial clustering characteristics. At the same time, RHSE shows dynamic persistence, indicating that the initial investment and accumulation in agricultural production directly affect current and subsequent periods of agricultural production activities. ② The impact of agriculture tourism integration on RHSE has a spatial spillover effect. For the entire study area, the increase in the level of agriculture tourism integration not only promotes the improvement of RHSE in this region, but also has a positive promoting effect on RHSE in surrounding areas. Regionally, the direct effect of agriculture tourism integration on RHSE is the strongest in the central region, and the spillover effect is the greatest in the eastern region. ③ The impact of agriculture tourism integration on RHSE has a typical stage-like and economic dependence. As the level of agriculture tourism integration increases, the impact of agriculture tourism integration on RHSE has a dual threshold feature, and the marginal effect of agriculture tourism integration generally undergoes a process from strong to weak and then strengthens. The impact of agriculture tourism integration on RHSE is constrained by the regional economic development level, and the regional economic development level presents a single threshold feature, that is, the impact effect of agriculture tourism integration

shows a continuous strengthening trend as the regional economic development level rises.

6.2 Policy recommendations

This study has found that the integration of agriculture and tourism has a significant positive effect on RHSE, and it also exhibits clear spatial spillover effects and threshold characteristics. Therefore, in the process of promoting the in-depth development of the integration of agriculture and tourism, it is urgent to strengthen institutional coordination, regional collaboration, and factor support, and to propose differentiated policy recommendations with spatial specificity based on the resource endowments and development foundations of different regions:

Firstly, the government should strengthen policy design and incorporate industrial integration into the framework of rural environmental governance. Differentiated paths should be implemented based on the characteristics of different regional integration stages. In the eastern region, it can further integrate its economic and ecological resources to ensure the sustainability of the improvement and promotion effect of agricultural tourism on RHSE; in the central region, it can utilize its rich ecological resources, fully leverage its ecological advantages, combine the resources it possesses to develop local characteristic industry, and form its own competitive advantages, making the improvement and promotion effect of agricultural tourism on RHSE more significant; in the western region, due to slower economic development, at this stage, it can rely on government support and guidance to develop local characteristic and advantageous industries, lay a certain foundation for the development of agriculture tourism integration, and seek new ideas and new means to discover regional development comparative advantages, enhance the level of agriculture tourism integration, and fully utilize policy advantages to promote the improvement of RHSE.

Secondly, based on the spatial spillover effect of agriculture tourism integration, a cross-regional collaborative governance mechanism should be established. Municipalities and provinces at all levels should strengthen exchanges and cooperation, build demonstration platforms for agriculture tourism integration exchanges, learn advanced experience, introduce characteristic development models, promoting the development of agriculture tourism integration. Neighbouring regions should also strengthen cooperation, taking ecological corridors and cultural corridors as the main lines, balancing the development resources among regions, forming a regional ecological collaborative development area with complementary advantages, enhancing regional agriculture tourism integration level, and actively promoting the improvement of RHSE and the enhancement of environmental benefits.

Finally, implement the “Talent Revitalization Project” in the agriculture tourism integration, build a multi-level talent training system, attract young entrepreneurs returning to their hometowns and multi-skilled talents, promote the downward transfer of university research resources and industry-academia integration, enhance the continuous driving force of agriculture tourism integration for environmental improvement through the improvement of human resource quality. And ultimately, a policy support system that is adapted to the phased characteristics of industrial integration and has spatial specificity will be formed.

6.3 Limitations

The main limitations of this study are as follows: Firstly, due to the limitation of data availability, this study employed provincial panel data for research. The geographical scope of the sample measurement is relatively large, which may affect the accuracy of the results. In the future, quantitative analysis can be conducted using smaller-scale sample data such as municipal panel data; Secondly, although the theoretical analysis part analyzed the mechanism by which agriculture tourism integration promotes rural human settlement environment, due to the length of the paper, the empirical part did not conduct in-depth examination of the influencing mechanism. In the future, this can be further tested through empirical analysis.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

ZL: Conceptualization, Data curation, Writing – original draft. CC: Methodology, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

References

- Ammirato, S., Felicetti, A. M., Raso, C., Pansera, B. A., and Violi, A. (2020). Agritourism and sustainability: what we can learn from a systematic literature review. *Sustainability* 12, 1–18. doi: 10.3390/su12229575
- Anselin, L. (1998). *Spatial econometrics: methods and models*. Dordrecht, Netherland: Kluwer Academic Publishers.
- Arellano, M., and Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equation. *Rev. Econ. Stud.* 58, 277–297. doi: 10.2307/2297968
- Ayyildiz, A. Y., and Koc, E. (2024). “Promotion of agritourism as a sustainable form of tourism” in Rethinking sustainable tourism in geographical environments: theory and practices (Cham: Springer Nature Switzerland).
- Bai, Y., and Wang, Z. (2019). A study on comprehensively improving the quality of rural living environment in Tianjin. 6th international conference on management science and management innovation (MSMI 2019), 69–73.
- Bigiotti, S., Costantino, C., and Marucci, A. (2024). Agritourism facilities in the era of the green economy: a combined energy audit and life cycle assessment approach for the sustainable regeneration of rural structures. *Energies* 17:1101. doi: 10.3390/en17051101
- Chang, H. H., Mishra, A. K., and Lee, T. H. (2019). A supply-side analysis of agritourism: evidence from farm-level agriculture census data in Taiwan. *Aust. J. Agric. Resour. Econ.* 63, 521–548. doi: 10.1111/1467-8489.12304
- Cheng, G., Dou, H., Xu, S., Dai, R., Liang, X., Huang, Y., et al. (2024). Rural human settlement environment improvement: process, status and China's sample. *Environ. Dev. Sustain.* 27, 17805–17832. doi: 10.1007/s10668-024-04686-3
- Ćirić, M., Tešanović, D., Pivarski, B. K., Ćirić, I., Banjac, M., Radivojević, G., et al. (2021). Analyses of the attitudes of agricultural holdings on the development of agritourism and the impacts on the economy, society and environment of Serbia. *Sustainability* 13, 1–15. doi: 10.3390/su132413729
- Cornelissen, A. M. G., van den Berg, J., Koops, W. J., Grossman, M., and Udo, H. M. J. (2001). Assessment of the contribution of sustainability indicators to sustainable development: a novel approach using fuzzy set theory. *Agric. Ecosyst. Environ.* 86, 173–185. doi: 10.1016/S0167-8809(00)00272-3
- Cui, J., Bi, X., and Ying, N. (2025). *Added-workload and Deducted-workload in grass-roots policy Implementation-A case study of the implementation of the rural living environment upgrade policy in S province's A town*. *Governance Studies*, 41, 65–80+158–159. doi: 10.15944/j.cnki.33-1010/d.2025.01.004
- Dax, T., Zhang, D., and Chen, Y. (2019). Agritourism initiatives in the context of continuous out-migration: comparative perspectives for the Alps and Chinese mountain regions. *Sustainability* 11, 1–13. doi: 10.3390/su11164418
- Deng, X. Y., Wang, Y. S., and Huang, H. (2023). Temporal and spatial evolution characteristics and driving factors of rural residential environment quality in Sichuan Province. *Journal of Agricultural Resources and Environment*, 40:1111–1121. doi: 10.13254/j.jare.2022.0328
- Doxiadis, C. A. (1968). *Ekistics: an introduction to the science of human settlements*. New York: Oxford University Press.
- Du, X., and Jiao, F. (2023). How the rural infrastructure construction drives rural economic development through rural living environment governance—a case study of 285 cities in China. *Front. Environ. Sci.* 11:1280744. doi: 10.3389/fenvs.2023.1280744
- Fidler, D., Olson, R., and Bezold, C. (2011). Evaluating a long-term livable communities' strategy in the U.S. *Futures* 43, 690–696. doi: 10.1016/j.futures.2011.05.010
- Foster, H. D. (1993). “Resilience theory and system evaluation” in Verification and validation of complex systems: human factors issues, Berlin, Heidelberg: Springer Berlin Heidelberg. 35–60.
- Gao, J., Barbieri, C., and Valdivia, C. (2014). Agricultural landscape preferences: implications for agritourism development. *J. Travel Res.* 53, 366–379. doi: 10.1177/0047287513496471

Acknowledgments

We appreciate the editors' and the reviewers' insightful comments of a previous draft of this manuscript.

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- Ha, M. (1989). The determinants of residential environmental qualities and satisfaction: toward developing residential quality indices. Oklahoma: Oklahoma State University.
- Halaby, C. N. (2004). Panel models in sociological research: theory into practice. *Annu. Rev. Sociol.* 30, 507–544. doi: 10.1146/annurev.soc.30.012703.110629
- Hatan, S., Fleischer, A., and Tchetchik, A. (2021). Economic valuation of cultural ecosystem services: the case of landscape aesthetics in the agritourism market. *Ecol. Econ.* 184:107005. doi: 10.1016/j.ecolecon.2021.107005
- Im, K. S., Pesaran, M. H., and Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *J. Econom.* 115, 53–74. doi: 10.1016/S0304-4076(03)00092-7
- Joo, H., Khanal, A. R., and Mishra, A. K. (2013). Farmers' participation in agritourism: does it affect the bottom line? *J. Agric. Resour. Econ.* 42, 471–490. doi: 10.1017/s1068280500004949
- Kaplan, S. C., Butler, R. M., Devlin, E. A., Testa, R. J., Horenstein, A., Swee, M. B., et al. (2019). Rural living environment predicts social anxiety in transgender and gender nonconforming individuals across Canada and the United States. *J. Anxiety Disord.* 66:102116. doi: 10.1016/j.janxdis.2019.102116
- Khanal, A. R., and Mishra, A. K. (2014). Agritourism and off-farm work: survival strategies for small farms. *Agric. Econ.* 45, 65–76. doi: 10.1111/agec.12130
- Kim, S. B., Cho, S. J., Kang, B. H., and Kim, H. M. (2003). Study on rural living environment and satisfaction by improving rural housing renewal project. *J. Korean Soc. Rural Plan.* 9, 9–16.
- Komeily, A., and Srinivasan, R. S. (2015). A need for balanced approach to neighborhood sustainability assessments: a critical review and analysis. *Sustain. Cities Soc.* 18, 32–43. doi: 10.1016/j.scs.2015.05.004
- Li, Y., Cao, L., Wang, P., and Chang, G. (2022). Rural living environment improvement and rural revitalization. *J. Nat. Resour.* 37, 96–109. doi: 10.31497/zrzyxb.20220107
- Li, D., Hou, L., Min, S., and Huang, J. (2021). The effects of rural living environment improvement programs: evidence from a household survey in 7 provinces of China. *Manag. World* 37, 182–251. doi: 10.19744/j.cnki.11-1235/f.2021.0163
- Li, Z., and Jia, W. (2025). Policy evolution and optimization strategies of rural human settlement environment governance since the founding of new China. *J. Party School CPC Zhengzhou Municipal Comm.* 3, 57–64. doi: 10.15875/j.cnki.zgzzswdxxb.2025.03.014
- Li, C., Zhu, X., Li, Y., et al. (2007). Study on concentrated rural residential areas and ecological human settlements construction in rapid urbanization regions. *J. Chongqing Univ. Arch.* 29, 1–5.
- Liang, C., Li, J. P., and Li, J. J. (2021). The evaluation of the quality of rural human settlements and its coordination with regional economy in China based on the production-living-ecological theory. *Chin. J. Agric. Resour. Reg. Plan.* 42, 19–30.
- Lin, S., and Hou, L. (2023). SDGs-oriented evaluation of the sustainability of rural human settlement environment in Zhejiang, China. *Heliyon* 9:e13492. doi: 10.1016/j.heliyon.2023.e13492
- Liu, Y. (2018). Urban–rural integration and rural revitalization in the new era of China. *Acta Geograph. Sin.* 73, 637–650.
- Liu, J., Zheng, B., and Tang, H. (2023). The science of rural human settlements: a comprehensive overview. *Front. Environ. Sci.* 11:1274281. doi: 10.3389/fenvs.2023.1274281
- Lupi, C., Giaccio, V., Mastronardi, L., Giannelli, A., and Scardera, A. (2017). Exploring the features of agritourism and its contribution to rural development in Italy. *Land Use Policy* 64, 383–390. doi: 10.1016/j.landusepol.2017.03.002
- Mitchell, J. (2012). Value chain approaches to assessing the impact of tourism on low-income households in developing countries. *J. Sustain. Tour.* 20, 457–475. doi: 10.1080/09669582.2012.663378
- Ndhlovu, E., and Dube, K. (2024). Agritourism and sustainability: a global bibliometric analysis of the state of research and dominant issues. *J. Outdoor Recreat. Tour.* 46:100746. doi: 10.1016/j.jort.2024.100746
- Newell, J. M., Lyons, R., Martin-Misener, R., and Shearer, C. L. (2009). Creating a supportive environment for living with stroke in rural areas: two low-cost community based interventions. *Top. Stroke Rehabil.* 16, 147–156. doi: 10.1310/tsr1602-147
- Pan, D., Yu, Y., and Ji, K. (2024). The impact of rural living environment improvement programs on the subjective well-being of rural residents in China. *Humanit. Soc. Sci. Commun.* 11, 1–17. doi: 10.1057/s41599-024-03052-y
- Rigg, J. (1985). The role of the environment in limiting the adoption of new rice technology in northeastern Thailand. *Trans. Inst. Br. Geogr.* 10, 481–494. doi: 10.2307/621893
- Schilling, B., Sullivan, K., and Komar, S. (2012). Examining the economic benefits of agritourism: the case of New Jersey. *J. Agric. Food Syst. Community Dev.* 3, 199–214. doi: 10.5304/jafscd.2012.031.011
- Sepahvand, F., Taghdisi, A., and Rezvani, M. R. (2021). The evaluation of residential environment quality in peri-urban villages (case study: Shiraz County). *J. Rural Res.* 12, 110–125. doi: 10.22059/jrrr.2020.298184.1471
- Solymannejad, R., Alibaygi, A., and Salehi, L. (2021). Barriers and facilitators of agritourism sustainable development in west of Mazandaran province. *Geogr. Environ. Plann.* 33:1454. doi: 10.22108/gep.2021.130270.1454
- Streifeneder, T. (2016). Agriculture first: assessing European policies and scientific typologies to define authentic agritourism and differentiate it from countryside tourism. *Tour. Manag. Perspect.* 20, 251–264. doi: 10.1016/j.tmp.2016.10.003
- Sun, Q. L., Fang, K. X., and Liu, T. P. (2020). Impact of social norms and public supervision on the willingness and behavior of farming households to participate in rural living environment improvement: empirical analysis based on generalized continuous ratio model. *Resour. Sci.* 42, 2354–2369. doi: 10.18402/resci.2020.12.08
- Testa, R., Galati, A., Schifani, G., Di Trapani, A. M., and Migliore, G. (2019). Culinary tourism experiences in Agri-tourism destinations and sustainable consumption—understanding Italian tourists' motivations. *Sustainability* 11, 1–17. doi: 10.3390/su11174588
- Tew, C., and Barbieri, C. (2012). The perceived benefits of agritourism: The provider's perspective. *Tourism Management*, 33, 215–224. doi: 10.1016/j.tourman.2011.02.005
- Valdivia, C., and Barbieri, C. (2014). Agritourism as a sustainable adaptation strategy to climate change in the Andean Altiplano. *Tour. Manag. Perspect.* 11, 18–25. doi: 10.1016/j.tmp.2014.02.004
- Van Sandt, A., and Thilmany Mcfadden, D. (2016). Diversification through agritourism in a changing U.S. landscape. *West. Econ. Forum*, 15, 52–58. Available online at: [https://ageconsearch.umn.edu/record/253469/files/Pages from WEFall2016-6](https://ageconsearch.umn.edu/record/253469/files/Pages%20from%20WEF%20Fall%202016-6)
- Villanueva-alvaro, J. J., Mondéjar-Jiménez, J., and Sáez-Martínez, F. J. (2017). Rural tourism: development, management and sustainability in rural establishments. *Sustainability* 9, 1–8. doi: 10.3390/su9050818
- Wang, P., Qin, X., and Li, Y. (2021). Satisfaction evaluation of rural human settlements in Northwest China: method and application. *Land* 10:813. doi: 10.3390/land10080813
- Wang, C., Yao, S., and Chen, C. (2005). Empirical research on the hollowing problem of rural settlements in China. *Sci. Geogr. Sin.* 25, 3257–3262.
- Wang, J., Zhou, F., Chen, C., and Luo, Z. (2023). Does the integration of agriculture and tourism promote agricultural green total factor productivity?—province-level evidence from China. *Front. Environ. Sci.* 11, 1–18. doi: 10.3389/fenvs.2023.1164781
- Wang, J., Zhou, F., Xie, A., and Shi, J. (2024). Impacts of the integral development of agriculture and tourism on agricultural eco-efficiency: a case study of two river basins in China. *Environ. Dev. Sustain.* 26, 1701–1730. doi: 10.1007/s10668-022-02781-x
- Wang, Y., and Zhu, Y. (2023). Exploring the effects of rural human settlement on rural development: evidence from Xianju County in Zhejiang Province, China. *Environ. Dev.* 46:100845. doi: 10.1016/j.envdev.2023.100845
- Wu, L. Y. (1990). Creating a new landscape of China's living environment. *Archit. J.* 8, 7–8.
- Wu, L. Y. (1996). Science of human settlements. *Urban Stud.* 1:62.
- Wu, L. Y. (1997). “Human settlements II” and human settlements environment science. *City Plann. Rev.* 3, 4–9.
- Wu, B. (2019). Study on the optimization of rural living environment in Guanzhong area of Shaanxi province based on new urbanization. *Chin. J. Agric. Resour. Reg. Plan.* 40, 70–77.
- Ye, G., Luo, S., Chen, Y., and Wang, Y. (2018). Study on countermeasures of rural living environment improvement. International symposium on advancement of construction management and real estate, 1145–1156. Available at: https://link.springer.com/chapter/10.1007/978-981-15-3977-0_88
- Yu, F. (2019). Rural Environmental Improvement under the Rural Revitalization Strategy. *Research on Socialism with Chinese Characteristics*, 2, 80–85.
- Yu, F., Hu, M., and Wang, G. (2022). Paths and countermeasures of rural living environment improvement for the long-range objectives through the year 2035. *China Soft Sci.* 7, 17–27.
- Zhang, F. (2021). Rural environmental governance from the perspective of daily life-taking the transformation of rural living environment as an example. *Jianghai Acad. J.* 4, 125–131.
- Zhang, H., Gu, C., Gu, L., and Zhang, Y. (2011). The evaluation of tourism destination competitiveness by TOPSIS & information entropy—a case in the Yangtze River Delta of China. *Tour. Manag.* 32, 443–451. doi: 10.1016/j.tourman.2010.02.007
- Zhang, T., He, D., Kuang, T., and Chen, K. (2022). Effect of rural human settlement environment around nature reserves on farmers' well-being: a field survey based on 1002 farmer households around six nature reserves in China. *Int. J. Environ. Res. Public Health* 19:6447. doi: 10.3390/ijerph19116447
- Zhang, M., Zheng, J., and Gao, Z. (2017). Rural living environment pollution control in Shandong province: policy characteristics, effectiveness, dilemma and path optimization. *J. Shandong Agric. Univ. Soc. Sci. Edit.* 19, 66–74+91.
- Zhao, X., Sun, H., Chen, B., Xia, X., and Li, P. (2019). China's rural human settlements: qualitative evaluation, quantitative analysis and policy implications. *Ecol. Indic.* 105, 398–405. doi: 10.1016/j.ecolind.2018.01.006
- Zhong, Y., Tang, L., and Hu, P. (2020). The mechanism and empirical analysis of the integration of agriculture and tourism to promote the optimization and upgrading of rural industrial structure: a case study of national demonstration counties of leisure agriculture and rural tourism. *Chin. Rural Econ.* 7, 80–98.
- Zhou, K., Lin, X., Shen, Y., and Wu, L. (2011). Comprehensive evaluation of residential environment quality in new rural construction in suburban Beijing. *Prog. Geogr.* 30, 361–368.
- Zhu, Z. (2023). Approaches and mechanisms of rural living environment governance and under the perspective of everyday life governance. *Local Gov. Res.* 1, 65–80.