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EDITED BY
Fuyou Guo,
Qufu Normal University, China

REVIEWED BY
Jie Wen,
Hunan University of Finance and Economics, China
Long Qian,
Nanjing University of Finance and Economics, China
Hai Li,
Hunan Women's University, China

*CORRESPONDENCE
Weiguo Jiang
jwghau666@163.com

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Can the integration of agriculture and tourism foster agricultural green development? An empirical analysis based on panel data from 30 provinces in China

Chen Chen[1], Jingjing Wang[2], Weiguo Jiang[1]* and Ailiang Xie[3]

[1]College of Public Administration and Law, Hunan Agricultural University, Changsha, Hunan, China,
[2]Business College, Hunan University of Humanities, Science and Technology, Loudi, Hunan, China,
[3]History and Culture College, Linyi University, Linyi, Shandong, China

The integration of agriculture and tourism, grounded in agricultural resources, not only offers new development opportunities for the agricultural sector but also steers it towards a greener and more sustainable trajectory. Using panel data from 30 provinces in China from 2011 to 2022, this study quantifies the levels of agriculture and tourism integration (ATL) and agricultural green development (AGD) in each province. Then, the study applies the fixed effects model, the spatial Durbin model, and the panel smooth transition regression (PSTR) model to empirically assess the impact of ATL on AGD, as well as its spatial spillover effect and its nonlinear characteristics. The findings are as follows: (1) Over the study period, both AGD and ATL exhibited steady growth, with marked spatial agglomeration effects; (2) ATL positively influenced AGD, suggesting that the integration of agriculture and tourism contributes to the green development of agriculture; (3) The impact of ATL on AGD exhibited significant spatial spillover effects, meaning that integrated agricultural-tourism development in one region can enhance AGD in its neighboring provinces; (4) The effect of ATL on AGD demonstrated nonlinear characteristics, with the influence of ATL on AGD intensifying as ATL increased. Based on these findings, the study proposes several policy recommendations, including strengthening top-level policy design, improving regional coordination mechanisms, and enhancing human capital cultivation, to foster deeper the integration of agriculture and tourism and to further accelerate the green development of agriculture.

KEYWORDS

integration of agriculture and tourism, agricultural green development, spatial spillover effect, non-linear effect, impact

1 Introduction

Since the reform and opening up, China has made significant strides in agricultural development. Statistics show that the country's total grain output increased from 430.7 million tons in 2003 to 706.5 million tons in 2024, marking 21 consecutive years of growth. Despite these achievements, the green development of China's agriculture still faces serious challenges. During the rapid modernization of agriculture, issues such as the excessive consumption of fossil energy, overuse of pesticides, and improper disposal of agricultural waste have led to severe agricultural non-point source pollution and carbon emissions (Li and Guan, 2023). Non-point source pollution from farmland has surpassed industrial point source pollution, becoming the largest source of environmental contamination in many regions of China.

To address these concerns, the report from the 18th National Congress of the Communist Party of China emphasized the importance of promoting green development and establishing a scientifically sound agricultural development model. The 19th National Congress report further highlighted the need to enhance green development and strengthen efforts to control agricultural non-point source pollution. In 2021, the Ministry of Agriculture and Rural Affairs unveiled the "14th Five-Year Plan for the National Green Development of Agriculture," which explicitly called for accelerating the creation of a green, low-carbon, and circular agricultural system, improving the management of agricultural non-point source pollution, and promoting carbon reduction and sequestration in agriculture and rural areas. In December 2024, the Ministry issued the "Guiding Opinions on Accelerating the Comprehensive Green Transformation of Agricultural Development and Promoting Rural Ecological Revitalization," recognizing the acceleration of green transformation in agriculture as a critical task to promote rural revitalization and strengthen China's agricultural power. In the new stage of development, transitioning agricultural production modes and achieving green development are considered essential to ensuring national food security and maintaining social and economic stability (Zhou et al., 2023).

On a practical level, since the 18th National Congress, China's agricultural development has made considerable progress in achieving green transformation, even in challenging circumstances. This progress is evidenced by the widespread adoption of green production methods, improved resource conservation and efficiency, and increased capacity for producing high-quality agricultural products. According to the China Agricultural Green Development Report, the country's agricultural green development index increased from 73.46 in 2012 to 77.90 in 2022, marking a 6.04% rise (Luo et al., 2024). Nevertheless, China's agricultural green development still faces several pressing issues, such as inadequate material and technical infrastructure, insufficient exploitation of scientific and technological innovation potential, and an underdeveloped policy and institutional support system. Therefore, there is an urgent need to identify new elements, models, and drivers to accelerate the process of agricultural green development.

The primary objective of green agricultural development is to harmonize "green" and "development," shifting agriculture from a model characterized by high resource consumption and significant environmental costs to one marked by high productivity, efficient resource use, and minimal environmental impact (Liu et al., 2020). Research on green agricultural development generally focuses on two key areas: (1) the measurement of green development levels (Oenema, 2020; Sun, 2022) and (2) the factors influencing green agricultural development (Liu et al., 2020; Luo et al., 2024; Schmidt-Traub, 2020; Wang et al., 2024a).

In terms of measurement, Hall and Kerr (1991) introduced the "Green Index" concept and developed an indicator system for evaluating green development. Building upon this, Huang et al. (2017) constructed an indicator system based on the DPSIR model to assess agricultural green development levels and regional disparities across China. Methodologically, techniques such as principal component analysis (Zhang et al., 2022), analytic hierarchy process (Zhang et al., 2018), entropy method (Zhao and Yu, 2019), and entropy-weighted TOPSIS (Li et al., 2023) are commonly used to evaluate green development levels in agriculture.

Regarding the factors influencing green agricultural development, existing studies have identified several key determinants, including the role of the internet (Wang et al., 2024a), digital inclusive finance (Guo et al., 2022), agricultural green technology (He and Liu, 2022), agricultural insurance (Hou and Wang, 2022), and policy factors such as low-carbon strategies (Luo et al., 2024; Chen and Chen, 2021; Sun, 2022). Other important factors include agricultural industrial agglomeration (Zhang et al., 2022) and urbanization (Ge et al., 2023; Li and Li, 2019), which also significantly impact the green development of agriculture.

In recent years, the scale of agricultural tourism, or leisure agriculture, has expanded rapidly as an important form of rural industry convergence. According to data from the Ministry of Culture and Tourism, in 2019, the total number of rural leisure tourists in China reached 3.2 billion, with the total consumption (output value) of rural tourism amounting to 850 billion yuan (Wang et al., 2023). While this indicator declined between 2020 and 2022 due to the COVID-19 pandemic, the output value of rural tourism exceeded 900 billion yuan in 2023 (as shown in Figure 1). By the end of 2022, a total of 388 national leisure agriculture and rural tourism demonstration counties had been established nationwide, along with 1,973 "Beautiful Leisure Villages of China" and 1,597 national-level key villages and towns for rural tourism. According to the United Nations World Tourism Organization, China became the country with the largest number of "Best Tourist Villages" in 2024. The integrated development of agriculture and tourism has become a crucial strategy for advancing rural revitalization in China.

With the deepening integration of agriculture and tourism, the development effects of this integration have garnered significant scholarly attention. A review of literatures reveals that most studies focus on the economic and social impacts of industrial integration on rural development. Economically, scholars argue that establishing effective linkages between agriculture and tourism can create new market opportunities and consumer demand, thereby fostering the high-quality development of both sectors (Chang et al., 2019; Fleischer and Tchetchik, 2005; Rogerson, 2012; Gao et al., 2014). Although agricultural products required for tourism represent only a portion of total agricultural output, tourism plays a vital role in ensuring the quality and safety of agricultural products and promoting broader economic growth (Huang et al., 2014; Renting et al., 2009). Additionally, numerous empirical studies have examined the impact of ATL on rural and regional economic growth (Schilling et al., 2012; Streifeneder, 2016). In terms of its social effects, the integrated development of agriculture and tourism helps strengthen the connection between urban and rural areas while contributing to the preservation of natural and cultural heritage (Gao and Wu, 2017; Joo et al., 2013). Environmentally, scholars assert that tourism provides

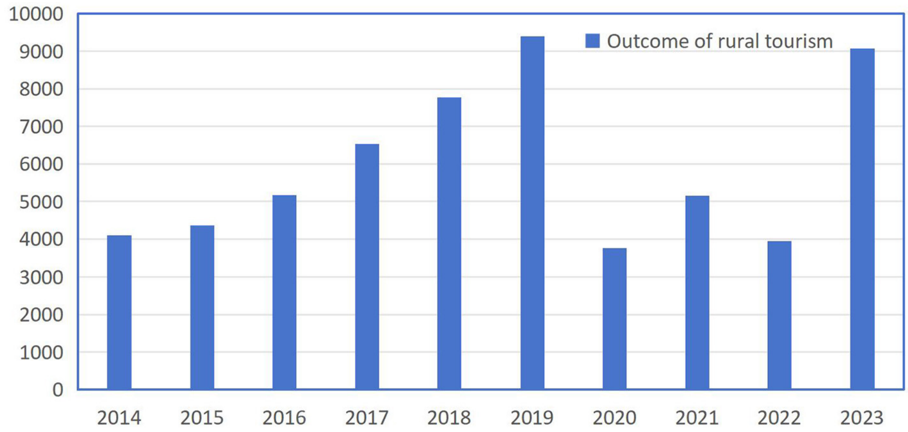

FIGURE 1
Change of total output value of rural tourism in China from 2014 to 2023.

farmers with an alternative source of income, which supports the green development of agriculture. This integration encourages the reallocation of part of the agricultural labor force and provides funding for the adoption of innovative technologies such as fertilizers. As a result, farmers can expand production without increasing tillage frequency or cultivating new land, thereby indirectly mitigating environmental degradation (Jiang, 2022; Kaswanto, 2015; Wang and Zhou, 2021).

However, few studies have explored the impact of agriculture and tourism integration on agricultural green development. Luo and Wei (2022) are among the few to analyze the environmental effects of rural industrial integration, particularly its impact on polluting production practices, providing preliminary evidence of its environmental implications. As a significant form of rural industrial integration, the connection between agriculture and tourism draws upon agricultural ecological resources, inherently influencing agricultural production methods and enhancing the green development of agriculture. Consequently, utilizing empirical analytical tools to examine the impact and characteristics of agriculture and tourism integration on agricultural green development is crucial for advancing both agricultural and tourism integration and promoting green agricultural development.

Against this backdrop, this study seeks to explore the following aspects: (1) measuring the levels of agricultural green development (AGD) across 30 provinces in China with panel data from 2010 to 2021; (2) quantifying the levels of agriculture and tourism integration (ATL) to better understand the dynamics between agriculture and tourism; (3) employing panel data and econometric models to assess the impact of agriculture and tourism integration on agricultural green development, including its spillover effects and non-linear characteristics; and (4) proposing specific policy recommendations to strengthen the role of agriculture and tourism integration in promoting green agricultural development.

The marginal contributions of this study are as follows: First, it expands the research scope regarding factors influencing agricultural green development. While previous studies have predominantly focused on technological and policy factors, this study innovatively introduces industrial integration as a significant variable, which also has an important reference value for exploring the road of agricultural green development. Second, it deepens the understanding of the impacts of agriculture and tourism integration by examine its ecological effects. In the past, a large number of studies focused on the impact of the integration of agriculture and tourism on rural economic development, farmers' income increase, farmers' local employment and the price of agricultural products. Through empirical analysis, this study explores the ecological implications of agriculture and tourism integration on agricultural green development, providing valuable insights for future research on the ecological outcomes of rural industrial integration.

2 Theoretical analysis and hypothesis

The integration of agriculture and tourism has significantly advanced the application and promotion of agricultural technologies, such as intelligent greenhouses, precision agriculture, and other technical innovations. These developments have enhanced the intelligence and precision of agricultural production, thereby fostering the growth of green agriculture (Wang et al., 2023). Moreover, this integration promotes the diversification and efficiency of agricultural development by leveraging the synergies between agriculture and tourism resources. Through this process, agricultural resources are utilized more fully and efficiently. To meet the demands of tourists, agricultural producers increasingly prioritize the quality and safety of their products, adopting green and organic production methods. This includes reducing the use of fertilizers and pesticides, which, in turn, mitigates agricultural non-point source pollution. Additionally, the integration of agriculture and tourism facilitates the extension and expansion of the agricultural value chain, such as the processing of agricultural products and the development of rural tourism offerings, further advancing the green and sustainable development of agriculture (Ayyildiz and Koc, 2024).

Building on existing research, this study develops a theoretical framework to examine the impact of agriculture and tourism integration on agricultural green development, with a focus on its spatial spillover effects and non-linear characteristics.

2.1. Influence mechanism of agriculture and tourism integration on agricultural green development

(1) The integration of agriculture and tourism can foster advancements in agricultural technology. The integration and evolution of agriculture and tourism have facilitated the spatial agglomeration of business units, the flow of talent, and the exchange of technologies (Wang et al., 2024b). Concurrently, the advanced technology and management expertise of tourism enterprises are disseminated to agricultural stakeholders, enhancing agricultural production and management capabilities (Ndhlovu and Dube, 2024). Furthermore, as agricultural resources are integrated and the "tourism" functions of agricultural products and activities (e.g., agriculture, animal husbandry, folk customs, leisure, vacation, and popular science education) are expanded, agricultural businesses increasingly introduce advanced agricultural technologies and management practices. This process plays a crucial role in enhancing agricultural technology levels.

(2) The integration of agriculture and tourism promotes the optimal allocation of resources. Under traditional agricultural management models, resource allocation primarily relies on limited capital, abundant land, and primary labor, resulting in relatively low efficiency in the allocation of agricultural production factors (Amsden and McEntee, 2011). However, the integration of agriculture and tourism facilitates the market-oriented flow and full interaction of capital, technology, talent, information, and management between the two sectors. This interaction promotes the optimal allocation of production factors at a higher level and significantly improves the efficiency of agricultural resource allocation (Soleimannejad et al., 2021). Moreover, new business models emerging from this integration create numerous non-agricultural employment and entrepreneurship opportunities for rural labor. Additionally, it encourages the moderate-scale and intensive management of agricultural land resources, thus leveraging economies of scale to achieve lower costs and higher efficiency (Ammirato et al., 2020).

(3) The integration of agriculture and tourism fosters the optimization and upgrading of agricultural industrial structure. The integration of agriculture and tourism has enriched rural tourism development, creating a diverse range of rural tourism products and services (Valdivia and Barbieri, 2014). For example, new types of businesses have emerged, such as national agricultural parks, leisure farms, rural camps, rural museums, citizen agricultural parks, and rural homestays. Driven by demand, these developments have led to adjustments in the allocation of agricultural production factors, optimizing the structure of agricultural production, quality, and variety. This shift in agricultural supply, aligned with changing market demand, enhances the efficiency of agricultural production and operations (Arru et al., 2019; Collins et al., 2024). The integration of agriculture and tourism fosters the development of agricultural versatility, meets the diverse needs of consumers for agricultural and tourism products, and drives improvements in agricultural technical efficiency and technological progress.

(4) The integration of agriculture and tourism enhances farmers' awareness of green environmental protection. With the rise of rural tourism, there has been growing demand among tourists for green, organic, and healthy agricultural products (Ndhlovu and Dube, 2024). This demand has prompted farmers to place greater emphasis on environmental protection and sustainability throughout the production process. Farmers are increasingly adopting green agricultural practices, such as organic farming techniques, reducing the use of fertilizers and pesticides, and improving the quality and safety of agricultural products (Ayyildiz and Koc, 2024; LaPan and Xu, 2024). In order to attract tourists, farmers are motivated to improve the agricultural production environment and enhance the green quality of their products, thus establishing a virtuous cycle of green production. The mechanism of agriculture and tourism integration on agricultural green development is illustrated in Figure 2.

Based on the above analysis, Hypothesis 1 is proposed: The integrated development of agriculture and tourism has a significant positive effect on the green development of agriculture.

2.2. Spatial spillover effects of agriculture and tourism integration on agricultural green development

The flow of tourism exhibits strong network diffusion effects. A distinctive feature of the tourism industry, compared to other sectors, is its cross-regional management. Given China's vast geographic expanse and significant regional variations in crop production cycles, the cross-regional operation of agriculture and tourism integration becomes both feasible and advantageous. This cross-regional interaction not only helps to expand market scale but also deepens the vertical division of labor within the agricultural system, facilitating economies of scale (Grillini et al., 2025). Furthermore, the seasonal nature of crop production enhances the mobility of agro-tourism visitors, fostering more efficient information and technology exchange between regions. Consequently, the integration of agriculture and tourism can influence the allocation of production factors, the agricultural industrial structure, and technological progress in neighboring areas through cross-regional operations, thereby impacting the green development of the agricultural system.

Based on the above analysis, Hypothesis 2 is proposed: The integration of agriculture and tourism has a spatial spillover effect in promoting agricultural green development.

2.3 Non-linear threshold characteristics of agriculture and tourism integration on agricultural green development

The process of integrating agriculture and tourism leads to the realization of agro-ecological premiums. However, in the early stages of this integration, the agro-ecological premium is relatively modest, and agricultural production predominantly relies on traditional methods (Grillini et al., 2025). During this period, the focus of agricultural production is primarily on enhancing efficiency, with little emphasis on actively reducing harmful

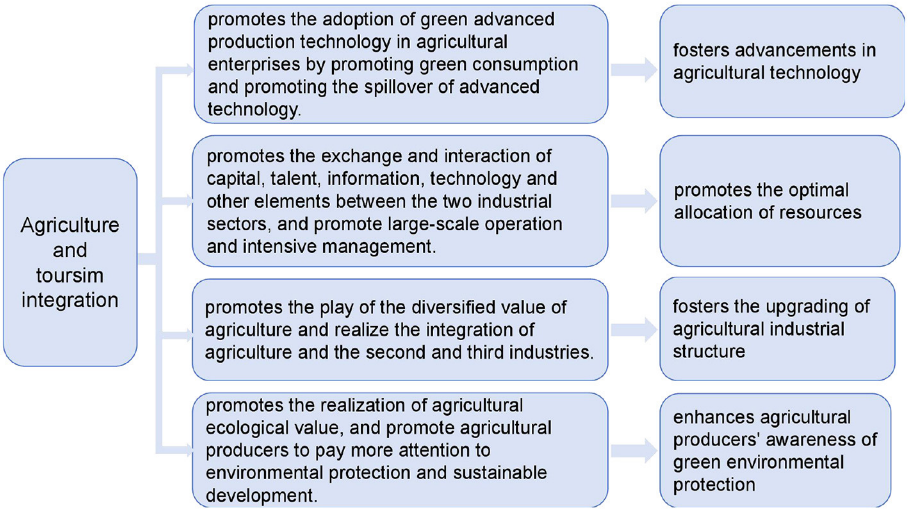

FIGURE 2
Mechanism of agriculture and tourism integration on agricultural green development.

environmental inputs such as fertilizers and pesticides. As a result, the integration of agriculture and tourism at this early stage did not significantly promote the green development of agriculture. As the integration progresses, the full agro-ecological premium becomes realized (Grillini et al., 2025). This shift encourages agricultural producers to prioritize green and sustainable agricultural practices, reducing the use of harmful inputs, and aiming for more substantial agro-ecological benefits (Bigiotti et al., 2024). Therefore, as the level of the integration of agriculture and tourism improves, its impact on the green development of agriculture is likely to intensify.

Based on the above analysis, Hypothesis 3 is proposed: There are threshold characteristics in the influence of the integration of agriculture and tourism on agricultural green development.

3 Methods and data

3.1 Variable selection

3.1.1 Explained variable

The agriculture green development (AGD_{it}) is the explained variable in this study. Based on researches of Xiong and Zhou (2024), Lu et al. (2024), and He et al. (2021), and adhering to the principles of comprehensiveness and representativeness, this study constructs an indicator system for measuring the level of agriculture green development. The system is structured around four dimensions: conservation of resources, environmental friendliness, ecological sustainability, and efficient output. Indicators for measurement for AGD are shown in Table 1.

The TOPSIS method with entropy is used to measure AGD in the study. In practice, there are many comprehensive evaluation methods. According to the different weights determined, there are subjective and objective weighted evaluation methods. In this study, the objective weighting method is used to determine the weight through the principle of information entropy, which can evaluate the research object objectively and accurately. To compare different methods, the entropy method is improved, and a time variable is added to make the analysis results more reasonable. The evaluation model of the improved entropy method is as follows:

(1) Index selection: with r years, n provinces, and m indicators, $x_{\theta ij}$ is the j-th index value of province i in the θ-th year.

(2) Standardization of indicators: Because different indicators have different dimensions and units, it is necessary to standardize them:
Standardization of the positive index:

$$x'_{\theta ij} = x_{\theta ij}/x_{\max} \tag{1}$$

Standardization of the negative index:

$$x'_{\theta ij} = x_{\min}/x_{\theta ij} \tag{2}$$

(3) Determine the index weight:

$$y_{\theta ij} = x'_{\theta ij}/\sum_{\theta}\sum_{i} x'_{\theta ij} \tag{3}$$

(4) Calculate the entropy of the j-th index:

$$e_j = -k\sum_{e}\sum_{i} y_{ij}\,\mathrm{In}\,(y_{\theta ij}),\ k > 0, k = \mathrm{In}\,(rn) \tag{4}$$

(5) Calculate the weight of each indicator:

$$w_j = g_j \,/\, \sum_{j} g_j \tag{5}$$

(6) Calculate the comprehensive score of the AGD level of each province:

$$AGD_{\theta i} = \sum_{i}(w_j x'\theta ij) \tag{6}$$

TABLE 1 Evaluation index system of agricultural green development.

First-level indicators	Secondary indicators	Measuring indicators	Unit	Attribute
Conservation of resources	Arable land replanting index	Total sowing area/cultivation area of crops	–	–
	Water-saving irrigation rate	Water-saving irrigation area/effective irrigation area	%	+
	Total mechanical power of arable land area per unit	Total power of agricultural machinery/arable land area	KW/hectare	–
	Agricultural water efficiency	Agricultural water consumption/total agricultural output	Ton/1 billion	–
	The intensity of pesticide application	Pesticide usage/arable land area	Ton/hectare	–
Environmental friendliness	Fertilizer application intensity	Agricultural fertilizer usage/arable land area	Ton/hectare	–
	The application strength of agricultural film	Agricultural film usage/total sowing area of crops	Ton/hectare	–
	Agricultural CO_2 emission intensity	Agricultural CO_2 emission intensity/total agricultural yield	Ton/1 billion	–
	The area of nature reserves	Nature reserve/jurisdictional area	%	+
Ecological protection	Forest coverage	Forest area, wetland area/Jurisdiction	%	+
	Wetland coverage rate	Wetland area/Jurisdiction	%	+
Efficient output	Soil erosion control rate	Soil erosion control area/Jurisdictional area	%	+
	Disposable income	Disposable income	Yuan	+
	The proportion of agricultural output	Agricultural output value/Total output value agriculture, forestry, animal husbandry and fisheries	%	+
	Land productivity	Agricultural output value/Crop sowing area	10 billion/Ton	+

3.1.2 Explanatory variable

The integration of agriculture and tourism (ATL_{it}) is the core explanatory variable, which is evaluated by coupling cooperation degree model. This requires selecting appropriate indicators to assess the development levels of both agriculture and tourism. A review of the literature reveals that agriculture and tourism integration refers to the process of establishing a distinct agricultural tourism brand based on regional characteristics of agricultural resources and integrating agricultural endowments with thematic or resource-based tourism. Key manifestations of agriculture and tourism integration include branded agricultural tourism towns centered on geographically indicated agricultural products, key tourism villages, leisure agriculture initiatives, and rural tourism demonstration counties, all of which encapsulate the defining features and elements of agriculture and tourism integration.

To enhance the specificity and rationality of agriculture and tourism integration measurement, this study uses publicly available data that reflect the development of agriculture and tourism integration, rather than generic indicators such as tourism revenue or agricultural output from statistical yearbooks. Based on the research of Yang et al. (2023), several indicators were selected to measure the levels of both distinctive agricultural development and rural tourism development with the entropy-weighted TOPSIS method. Indicators for the measurement are shown in Table 2.

The coupling cooperation degree model is used to evaluate ATL. The construction process of coupling coordination degree model of characteristic agriculture and rural tourism to evaluate ATL is as follows:

① Standardize the data of evaluation index:

When the evaluation index is a positive index:

$$y_{ij} = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j} \tag{7}$$

When the evaluation index is a negative index:

$$y_{ij} = \frac{x_{\max} - x_j}{\max x_j - \min x_j} \tag{8}$$

② Calculate the information entropy:

$$h_j = -k \sum_{i=1}^{m} p_{ij}\, In\, p_{ij} \; (\text{Where } p_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}}, k = \frac{1}{Inm}) \tag{9}$$

Define the weight of the j-th indicator as:

$$w_j = \frac{1 - h_j}{\sum_{j=1}^{n}(1 - h_j)} \; (\text{where } w_j \in [0,1], \text{and} \sum_{j=1}^{n} w_j = 1) \tag{10}$$

③ Calculate the development level of agriculture and tourism industry, respectively. The agricultural comprehensive evaluation function was determined and established according to the linear weighting method:

$$A(x) = \sum_{j=1}^{n} w_j M_{ij} \tag{11}$$

In the Formula (11), j is the number of evaluation indexes of agricultural development level, w_j is the weight of indexes,

TABLE 2 Measurement index system of agriculture and tourism integration.

First-level indicators	Secondary indicators	Attribute	Source of data
Characteristic agriculture	The number of geographical indications of agricultural products (s)	+	Ministry of Agriculture and Rural Affairs
	The number of "one village, one brand" project brands (s)	+	Ministry of Agriculture and Rural Affairs
	The output value of special agricultural products (billion yuan)	+	Ministry of Agriculture and Rural Affairs
	The number of advantageous agricultural products with local characteristics (s)	+	Ministry of Agriculture and Rural Affairs
	Orchard area (thousand hectares)	+	Yearbook of China's Rural Statistics
Rural tourism	The number of key townships of rural tourism in the county (s)	+	Ministry of Culture and Tourism
	The number of famous towns and villages in national characteristic landscape tourism (s)	+	Ministry of Housing and Urban-Rural Development
	The number of A-level scenic spots (s)	+	China Tourism Yearbook
	The number of demonstration counties for leisure agriculture and rural tourism(s)	+	Ministry of Culture and Tourism
	Rural tourism and leisure agricultural income (billion yuan)	+	Ministry of Culture and Tourism

and M_{ij} is the standardized value of the j-th agricultural index in the i-th year. The higher the value of $A(x)$ is, the higher the level of comprehensive agricultural development is, and vice versa. Similarly, the comprehensive evaluation function of tourism industry is established:

$$T(y) = \sum_{i=1}^{n} w_j N_{ij} \tag{12}$$

The interpretation of each indicator in Formula (12) is similar to Formula (11). The larger the value of $T(y)$ is, the higher the development level of tourism is, and vice versa.

④ The coupling coordination model of agriculture and tourism industry is established as follows:

$$C = \sqrt[2]{\frac{A(x) \cdot T(y)}{(A(x) + T(y))^2}} \tag{13}$$

$$D = \beta \cdot A(x) + \gamma \cdot T(y) \tag{14}$$

$$ATL = U = \sqrt{C \cdot D} \tag{15}$$

In Formula (13), C is the coupling degree, $C \ \varepsilon \ [0, 1]$. The greater the value of C is, the more ideal the degree of integration of the two industries is, and vice versa. The coupling degree C only reflects the interaction and cross state of agriculture and tourism industry, and cannot accurately reflect the actual integration and development level of the two industries. In order to avoid the illusion that the development level of the two subsystems is not high but the coupling degree of them is high, the coupling coordination degree U is used to represent the integration level of agriculture and tourism (ATL). The larger the U value, the better the coupling coordination. Generally speaking, the greater the value of coupling coordination degree is, the higher the degree of integration between industries is Su (2020). In Formula 15, β and γ are undetermined coefficients, and D is the comprehensive coordination index of agriculture and tourism industry. In view of the interactional relationship between agriculture and tourism industry system in the process of integration, this paper follows the view of Wang (2018), making $\beta = \gamma = 0.5$.

3.1.3 Control variables

Based on the current state of agricultural development, this study selects six control variables: financial support for agriculture (Fsa), agricultural industry structure (Ais), human capital (Huc), industrialization level (Ins), urbanization rate (Urb), and the level of economic development (IGDP). These variables are defined and measured as follows:

Fiscal support for agriculture (Fsa): This is measured by the proportion of local government expenditures on agriculture, forestry, and water resources relative to total local budget expenditures. Increased fiscal support for agriculture enhances the external environment for agricultural development, which significantly impacts agricultural green development (Zhang et al., 2022).

Industrialization level (Ins): Studies have shown a strong correlation between industrialization and agricultural green development. The level of industrialization is quantified by the proportion of the added value of the secondary industry in relation to the total GDP (Li et al., 2023).

Agricultural industry structure (Ais): This is represented by the proportion of the added value of crop production relative to the total added value of agriculture, forestry, animal husbandry, and fisheries. A higher proportion of crop production generally indicates a more concentrated agricultural production structure, which may have a positive influence on agricultural green development (Sun, 2022).

Human capital (Huc): This variable is measured by the proportion of college graduates per 100,000 rural residents. In general, higher levels of education among agricultural producers facilitate the acquisition of production skills and the rational use of chemical inputs, which is expected to positively influence agricultural green development.

Urbanization rate (Urb): The urbanization rate is calculated as the proportion of the urban population relative

TABLE 3 Descriptions of the variables and their specific measurements.

Variable	Variable name	Unit	Calculation method	Data source
Explained variable	Agricultural green development (AGD)	_	Calculated by entropy power TOPSlS method	Shown in Table 1
Explanatory variable	The integration of agriculture and tourism (ATL)	_	Calculated by coupling cooperation degree model	Shown in Table 2
Control variables	Financial support for farmers (Fsa)	%	lt is expressed in the proportion of agricultural, forestry and water conservancy expenditure to local expenditure in the total local budget	China's rural economy
	Agricultural industry structure (Ais)	%	Represented by the proportion of the added value of the planting industry to the added value of agriculture, forestry, animal husbandry and fishery	
	Human capital (Huc)	%	Expressed by the proportion of college students per 100,000 people in rural areas	China Statistical Yearbook
	Industrialization level (Ins)	%	It is expressed by the proportion of the added value of the secondary industry to the total output value.	
	Urbanization rate (Urb)	%	Expressed by the proportion of urban population in each province to the resident population	
	The level of economic development (IGDP)	—	Represented in the logarithm of GDP per capital	

to the total permanent population in each province. As the agricultural production model shifts from extensive to intensive practices, the increased use of pesticides and fertilizers, aimed at boosting yields, contributes to higher agricultural carbon emissions, hindering progress in agricultural green development.

Regional economic development level (IGDP): This is represented by the logarithm of per capita GDP, adjusted for inflation. Descriptions of all variables and their specific measurements are shown in Table 3.

3.2 Empirical model specification

3.2.1 Fixed effects model

The fixed effects model is capable of controlling unobservable factors that remain constant over time, effectively addressing errors caused by omitted variables in the model. In this study, the panel model with fixed effects is established as the benchmark regression model, which is formulated as follows:

$$AGD_{it} = \alpha_0 + \beta_1 ATL_{it} + \sum_{k=1}^{n} \lambda_k \, Col_{it,\,k} + \mu_i + \nu_t + \xi_{it} \quad (16)$$

In the above formula, *AGDit* and *ATLit* represent the explained variable and the core explanatory variable, respectively. Subscripts i and t denote province and year, respectively, while *Colit, k* refers to a set of control variables.

3.2.2 Spatial Durbin Model

When both the explained variable and explanatory variables exhibit spatial correlation, it is necessary to construct a Spatial Durbin Model (SDM). Considering the potential spatial dependence between the explained variable AGD and the explanatory variable ATL, the following SDM is constructed:

$$AGD_{it} = \alpha_0 + \rho WAGD_{it} + \beta ATL_{it} + \gamma Cit, k + \theta WATL_{it} + \xi W \sum_{k=1}^{n} C_{it,\,k} + \mu_i + \nu_t + \varepsilon_{it} \quad (17)$$

In the above formula, ρ represents the spatial correlation coefficient, W is the spatial weight matrix, the geographical distance spatial matrix (W) is used in the spatial econometric model. The calculation formula is, d_{ij} is the direct distance between two provincial capitals and other variables are defined as in Formula (17).

3.3.3 Panel smooth transition regression (PSTR) model

The promotion effect of agriculture and tourism integration on AGD may also show non-linear characteristics, so the panel smooth transition regression (PSTR) model is used to test the non-characteristic characteristics of agriculture and tourism integration on AGD. The specific model is set as follows:

$AGD_{it} = \beta_{01}ATL_{it} + \beta_{02}Fsa_{it} + \beta_{03}Ais_{it} + \beta_{04}Huc_{it} + \beta_{05}IGDP_{it+}\beta_{06}Ais_{it+}\beta_{07}Urb_{it+}(\beta_{01}ATL_{it+}\beta_{02}Fsa_{it} + \beta_{03}Ais_{it} + \beta_{04}Huc_{it} + \beta_{05}\ IGDP_{it+}\beta_{06}Ais_{it+}\beta_{07}Urb_{it})\cdot g\ (q_{it};r,c) + \mu_i + \varepsilon_{it}$

Where $g(q_{\mathrm{it}};\ r,\ c)$ represents the conversion function, and the formula for the conversion function is as follows:

$$g(q_{it}; r, c) = \left\{1 + \exp\left[-r \prod_{j=1}^{m} (q_{it} - c_j)\right]\right\}^{-1}, \quad (18)$$
$$r > 0, c_1 \le c_2 \le \cdots \le c_n, r > 0, c_1 \le c_2 \le \ldots \le c_n$$

In Formula (19), the explained variable is AGD_{it}, the explanatory variable and the conversion variable are both ATL_{it},

TABLE 4 Description of variables.

Variables	Samples	Mean	Median	Std. dev	Max	Min
AGD_{it}	360	0.665	0.692	0.115	0.824	0.468
ATL_{it}	360	0.661	0.689	0.121	0.853	0.376
Fsa_{it}	360	0.109	0.101	0.065	0.179	0.084
Ais_{it}	360	0.516	0.515	0.583	0.865	0.303
Huc_{it}	360	0.028	0.025	0.008	0.064	0.010
Ins_{it}	360	0.404	0.398	0.075	0.792	0.254
Urb_{it}	360	0.554	0.542	0.139	0.895	0.211
$IGDP_{it}$	360	1.092	1.116	0.505	2.316	−0.143

and the other variables are interpreted as above. In Formula (20), q_{it} is the conversion variable; r is the slope parameter, which determines the conversion speed; c is the position parameter, which determines the threshold condition of parameter conversion; m is the number of positional parameters. In the PSTR model, the variable estimation coefficient is composed of the linear part β_0 and the non-linear part β_1*g(·). When g(·) = 0, the model is in a low regime; When g(·) = 1, the model is in a high regime. At the same time, as the value of the conversion function moves smoothly between [0, 1], the estimated coefficient will monotonically shift between β_0 to $\beta_0 + \beta_1$, centered on c (González et al., 2005).

3.3 Data source and variable characteristics

3.3.1 Data source

Data of 30 provinces in China from 2011 to 2022 are used in this study to conduct the empirical analysis. Considering the lack of data from Hong Kong, Macao, Taiwan and Tibet Autonomous Region, the above four provinces are not included in the analysis. The data mainly are drawn from the National Bureau of Statistics, the Ministry of Culture and Tourism, the Ministry of Agriculture and Rural Affairs, the provincial statistical bureau and statistical bulletins. All data measured in monetary units are deflated at the 2011 price level. Some missing data values are supplemented by mean difference, linear interpolation and moving average method. Z-score standardization method is used to convert variables to dimensionless numerical values, eliminating the impact of units. In addition, R language and GeoDa software are used for quantitative analysis.

3.3.2 Variable characteristics

The descriptive statistical results of each variable are shown in Table 4.

Using provincial panel data, this study calculates the levels of AGD and agriculture tourism integration for each province from 2011 to 2022. The average annual values of AGD and agriculture and tourism integration over the study period are presented in Figure 3.

Overall, AGD demonstrated steady improvement from 2011 to 2022, with an average annual growth rate of 3.819%. In recent years, the central government's increasing emphasis on sustainable agricultural development had significantly contributed to this progress. During the study period, the average annual growth rates of AGD in the eastern, central, and western regions were 3.836%, 3.860%, and 3.834%, respectively. Notably, the eastern region consistently exhibited a higher agricultural green development growth rate compared to other regions. This can likely be attributed to its stronger economic foundation, which facilitates the adoption and dissemination of advanced green production technologies.

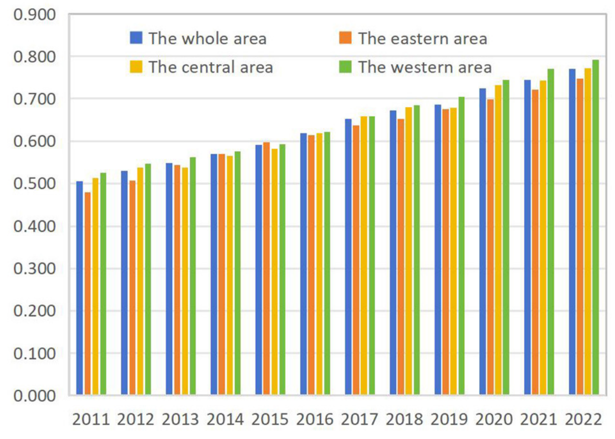

FIGURE 3
The mean value of AGD from 2011 to 2022 in China.

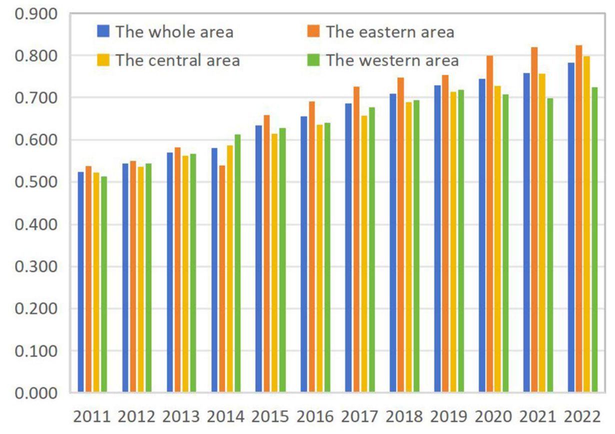

FIGURE 4
The mean value of ATL from 2011 to 2022 in China.

The annual average value of agriculture and tourism integration across the entire study area also showed an upward trend, with an average annual growth rate of 3.722%. This growth was primarily driven by the substantial role of rural industrial integration in promoting income generation and employment, an area that has received strong support from governments at various levels. Regionally, the eastern region had the highest average agriculture and tourism integration, while the western region exhibited relatively lower average agriculture and tourism integration, as illustrated in Figure 4. The eastern region benefited from a robust economic foundation, well-developed transportation

TABLE 5 Full sample estimation results.

Variables	FE	RE	POLS
ATL_{it}	0.512***(5.969)	0.206***(5.418)	0.337***(4.315)
Fsa_{it}	1.311***(8.165)	1.234***(7.136)	1.128***(8.191)
Ins_{it}	0.021**(3.118)	0.017**(3.042)	0.014**(3.139)
Huc_{it}	0.148***(6.136)	0.117***(5.854)	0.094***(4.176)
$IGDP_{it}$	0.213*(1.998)	0.206(0.418)	0.274**(3.143)
Ais_{it}	0.020***(4.418)	0.028**(3.136)	0.015*(2.418)
Urb_{it}	−0.348***(-3.649)	−0.198*(-2.143)	−0.144**(-2.842)
N	360	360	360
R^2	0.734	0.695	0.611

***, **, and * represent $P < 0.01$, $P < 0.05$, and $P < 0.1$ respectively, and the T-value is in parentheses.

infrastructure, and comprehensive public services. These factors, coupled with higher levels of regional economic development and stronger market demand, had fostered a higher degree of agriculture and tourism integration. In contrast, the western region lacked some of these driving forces, resulting in comparatively lower levels of agriculture and tourism integration.

4 Results and discussion

4.1 Benchmark model estimation results and analysis

4.1.1 Estimation results of fixed effect model

As shown in Table 5, the regression coefficient of ATL on AGD is 0.512 ($P < 0.05$), indicating a statistically significant positive impact of ATL on AGD. This relationship underscores the alignment of ATL with the principles of "agriculture-oriented development" and ecological sustainability, with agriculture and rural areas serving as foundational pillars. The integration process fosters the transition toward more intensive and environmentally friendly agricultural production and operations.

Throughout the deepening of ATL, resources and elements originally confined to agriculture, tourism, and related sectors are synergistically combined, giving rise to innovative business models such as "agriculture + tourism + sports," "agriculture + tourism + wellness," and "agriculture + tourism + education." These new models unlock synergies between tourism and agriculture, facilitating the transformation of traditional agricultural practices into more ecologically sustainable forms. By injecting fresh momentum into rural development, expanding the functional scope of agriculture, and fostering novel economic growth patterns, these models generate new sources of value creation, ultimately driving the advancement of AGD.

4.1.2 Robustness and eogeneity test

(1) Robustness test

To ensure the robustness of the benchmark regression results, several methods were employed for endogeneity and robustness testing:

First, using the lag term of ATL for regression: At the time level, considering the lag effect of ATL on AGD, the first-order lag term and second-order lag term of ATL are used as the core explanatory variables for regression.

Second, changing the number of bootstrap iterations:Panel data analysis typically assumes that disturbance terms are independent across individuals and uncorrelated over time within the same individual. However, to account for potential heteroscedasticity and autocorrelation, cluster-robust standard errors at the provincial level may be less accurate in small samples. Therefore, the bootstrap method, which provides more reliable estimates, was applied. The number of bootstrap iterations was set to 500 to ensure robustness.

Third, changing the sample size: Municipalities directly under the central government, such as Beijing, Shanghai, Tianjin, and Chongqing, often experience more pronounced benefits from national policies. These municipalities are better positioned to accelerate economic decision-making, implement urban renewal strategies tailored to local conditions, and unlock untapped urban potential. To account for this, the samples of these four municipalities were excluded, and the fixed effects model was re-estimated.

Under the three robustness tests, ATL can significantly increase AGD, which proves the robustness of the baseline regression results.

(2) Endogeneity test

In order to alleviate the possible endogeneity problem of the model, IV-2SLS method was used to deal with it. The density of highway network is used as the instrumental variable, and the selection of the instrumental variable needs to meet two conditions of correlation and externality: First, the development level of the integration of agriculture and tourism is often closely related to transportation infrastructure, so the integration level of agriculture and tourism can be characterized by the density of highway network to a certain extent, so the condition of correlation between independent variable and instrumental variable is satisfied. Secondly, the density of highway network does not directly affect the green development of agriculture, so the exogenous conditions of instrumental variables are satisfied.

The results of columns (1) and (2) in Table 6 show that: in the first stage, instrumental variables and ATL has positive correlation, and the higher the density of highway network, the better the historical infrastructure conditions, and the more conducive to the subsequent integrated development of agriculture and tourism; In the second stage, the effect of ATL on AGD is still significantly positive at the level of 1%, and all pass the validity test of instrumental variables.

4.2 Estimation results and analysis of spatial panel model

4.2.1 Identification of spatial model

Before estimating the model, the spatial correlations between ATL and AGD over the years were tested. The calculated Global

TABLE 6 Robustness and eogeneity tests.

Variables	Instrumental variable method		Alternate explanatory variable		Bootstrap iterations was set to 500	Changing the Sample Size
	First stage	Second stage	One-phase lag	Two-phase lag		
ATL		0.498*** (3.593)	0.546*** (3.354)	0.324*** (5.113)	0.417** (2.917)	0.696*** (3.323)
IV	0.643*** (4.593)					
Control variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Year	√	√	√	√	√	√
Province	√	√	√	√	√	√
$Adj\ R^2$	0.932	0.795	0.694	0.637	0.593	0.621
N	360	360	330	300	360	324
Unidentifiable test	12.984***					
Weak instrumental variable testing	209.462					

*** and ** represent $P < 0.01$ and $P < 0.05$ respectively, and the t-value is in parentheses.

TABLE 7 Test results of the spatial model.

Spatial correlation test	*LM-lag*	*Robust LM-lag*	*LM-error*	*Robust LM-error*
	9.414***	17.312***	0.576	5.811**
Wald statistic and LR statistic test	*Wald-spatial lag*	*LR-spatial lag*	*Wald-spatial error*	*LR-spatial error*
	23.785***	11.094***	14.091***	5.676**

*** and ** represent $P < 0.01$ and $P < 0.05$ respectively, and the t-value is in parentheses.

Moran's I values for both variables were positive and statistically significant at the 1% confidence level across all years, indicating substantial spatial correlations for both ATL and AGD. This suggests that spatial factors must be incorporated when analyzing the relationship between these two variables.

To determine the most appropriate spatial econometric model, the two-step procedure proposed by Elhorst (2003) was applied. The results revealed that both the Wald and LR statistics were significant, suggesting that the Spatial Durbin Model (SDM) is the most suitable model for fitting the sample data. The test results are presented in Table 7. Additionally, a Hausman test was conducted, yielding a test statistic of 32.675 ($P < 0.000$), which supports the use of the fixed effects model as the more appropriate specification.

4.2.2 Results of the SDM

Based on the above estimations, the fixed effects Spatial Durbin Model (SDM) is identified as the optimal model for this study. The estimation results are presented in Table 8. As shown in Table 8, in the two-ways fixed effects SDM, the regression coefficient of ATL on AGD is 0.475, indicating that for every unit increase in ATL, AGD increases by 0.475 units. In contrast, the ATL coefficient in the fixed effects panel model is 0.237. This indicates that the impact of ATL on AGD is greater in the two-ways fixed effects panel model than in the spatial effects panel model. This discrepancy suggests that the

TABLE 8 Estimation results of Spatial Durbin Model.

Variables	Two-ways fixed effect model	Time fixed effect model	Spatial fixed effect model
ATL_{it}	0.475**(2.997)	0.172*(2.315)	0.237**(3.352)
Fsa_{it}	1.245**(3.186)	1.128(1.191)	1.170(0.966)
Ins_{it}	0.026**(1.969)	0.025(0.139)	0.043*(2.118)
Huc_{it}	0.135**(3.326)	0.173**(3.176)	0.209**(2.765)
$IGDP_{it}$	0.201***(4.180)	0.274*(3.143)	0.274*(2.195)
Ais_{it}	0.014*(2.496)	0.005(0.989)	−0.001*(2.383)
Urb_{it}	−0.314***(-3.379)	−0.165**(-2.760)	−0.209**(-2.894)
$W^{*}ATL_{it}$	0.175**(3.097)	0.081*(2.035)	0.137**(2.954)
$Adj\ R^2$	0.920	0.763	0.587
ρ	0.321***(3.841)	0.206***(3.635)	0.215**(2.819)
$Log\ L$	193.143	155.043	119.758

***, **, and * represent $P < 0.01$, $P < 0.05$, and $P < 0.1$ respectively, and the t-value is in parentheses.

two-ways fixed effects model may overestimate the positive effects of ATL on AGD when spatial factors are ignored. Furthermore, the spillover coefficient (ρ) is positive and significant, indicating that AGD in one region has a positive spatial spillover effect on AGD in neighboring regions.

Due to the presence of spatial spillover effects, the coefficient of ATL cannot be interpreted as the marginal effect on AGD in a straightforward manner. Therefore, it is necessary to decompose the estimated results to more accurately reveal both the direct (local) and indirect (spatial spillover) effects of ATL on AGD. The results of the spatial effects decomposition are presented in Table 9.

Regarding the direct effects, the direct (local) effect of ATL on AGD is estimated at 0.471 ($P < 0.05$). This suggests that for every unit increase in a region's ATL level, the level of AGD in that region improves by 0.471 units. In terms of indirect (spillover) effects, the indirect effect of ATL on AGD is 0.245 ($P < 0.05$), as

TABLE 9 Decomposition results of spatial effects.

Variables	ATL_{it}	Fsa_{it}	Ins_{it}	Huc_{it}	$IGDP_{it}$	Ais_{it}	Urb_{it}
Direct effect	0.471** (3.056)	1.215* (2.016)	0.016* (2.118)	0.095** (3.187)	0.193** (2.914)	0.021** (2.587)	−0.246** (−2.653)
Indirect effect	0.245** (3.125)	0.055 (1.027)	0.003 (0.735)	0.011* (2.295)	0.016** (3.021)	0.010* (2.769)	−0.021** (−3.191)
Total effect	0.716* (2.159)	1.270* (1.986)	0.019* (1.992)	0.106* (2.131)	0.209** (3.125)	0.031** (2.860)	−0.267** (-2.983)

** and * represent $P < 0.05$ and $P < 0.1$ respectively, and the t-value is in parentheses.

TABLE 10 Estimates for different regions.

Variable	Eastern area	Central area	Western area	Variable	Eastern area	Central area	Western area
ATL_{it}	0.466** (2.738)	0.524** (3.153)	0.480** (3.074)	W^*ATL_{it}	0.332* (2.154)	0.362* (1.971)	0.277* (2.041)
Fsa_{it}	1.262* (2.003)	1.231* (1.995)	1.339* (2.421)	W^*Fsa_{it}	0.063 (0.874)	0.043 (1.615)	0.105 (1.241)
Ins_{it}	0.016* (1.984)	0.033* (2.068)	0.036* (2.241)	W^*Ins_{it}	0.132 (1.030)	0.081 (1.287)	0.039 (1.144)
Huc_{it}	0.181** (3.154)	0.149** (3.086)	0.164 (1.663)	W^*Huc_{it}	0.281* (2.116)	0.149* (2.089)	0.141 (1.093)
$IGDP_{it}$	0.232* (2.132)	0.215** (3.221)	0.109** (3.042)	W^*IGDP_{it}	0.081* (2.276)	0.073** (2.901)	0.109* (2.324)
Ais_{it}	0.072* (2.415)	0.015** (3.064)	0.009* (2.255)	W^*Ais_{it}	0.102* (2.098)	0.015* (2.917)	0.009 (0.982)
Urb_{it}	−0.332* (-2.132)	−0.215** (-2.875)	−0.209** (-2.691)	W^*Urb_{it}	−0.053* (-2.132)	−0.103** (-3.210)	−0.096** (-2.943)
$Adj\ R^2$	0.8984	0.8473	0.8265	ρ	0.221** (2.841)	0.287** (2.605)	0.185** (2.675)
$LogL$	163.622	185.732	149.736				

** and * represent $P < 0.05$ and $P < 0.1$ respectively, and the t-value is in parentheses.

shown in Table 9. This finding indicates that a one-unit increase in ATL in a given region results in a 0.245 unit increase in AGD in neighboring regions.

As agricultural tourism infrastructure continues to develop and differentiated business models are implemented, regions that are first to overcome transformation challenges and bottlenecks are more likely to attract consumer preference. These regions thus draw more consumers, both locally and from surrounding areas, creating new consumption growth centers and demonstration effects (Madaleno et al., 2019). In response to competitive pressures, neighboring regions are likely to leverage their local tourism resources to develop unique business models. Thus, the integration of agriculture and tourism in one region not only directly stimulates the development of rural industries within that region but also promotes innovation and catch-up in neighboring areas. The integration of agriculture and tourism drives the upgrading of agricultural structures and the transformation of economic development models within a region (Zhong et al., 2022). This transformation impacts labor distribution, agricultural industrial layouts, capital flows, and land transfer mechanisms in neighboring areas, improving ecological environmental protection and agricultural development. In turn, this fosters AGD. Additionally, the development of ATL encourages the spatial diffusion of tourism flows and production innovation, thereby advancing the integration of agriculture and tourism in neighboring regions.

4.2.3 Analysis of spillover effects in different regions

Given the potential regional differences in the impact of ATL on AGD, this study further divides the research area into eastern, central, and western regions for analysis. The Spatial Durbin Model (SDM) with two-ways fixed effects was employed for estimation, and the results are presented in Table 10. The analysis shows that the estimation results for the eastern, central, and western regions are generally consistent with those for the full sample: both the direct (local) effects and spatial spillover effects are significant. This indicates that the findings from the overall analysis are relatively robust.

TABLE 11 Decomposition results of spatial effects in different regions.

Variables	Eastern area	Central area	Western area
Direct effect	0.451**(2.975)	0.513**(2.997)	0.465**(3.091)
Indirect effect	0.335**(3.031)	0.291**(3.115)	0.226**(2.606)
Total effect	0.786**(2.786)	0.804**(3.113)	0.691**(2.867)

** represents $P < 0.05$, and the t-value is in parentheses.

At the same time, considering the direct (local) effect of ATL on AGD and the spatial spillover effect, the difference of spillover effect between different regions was analyzed. The decomposition results of spatial effects are shown in Table 11. The direct (local) effect in the central and western regions is greater than that in the eastern region, and the direct (local) effect in the central region is the strongest. This result may be due to the fact that the central region has a good resource base for the integration of agriculture and tourism, but its AGD level is not so high, as shown in Figure 3. Therefore, the marginal effect of the integrated development of agriculture and tourism on the green development of agriculture is more prominent. In terms of spatial spillover effect, the spillover effect (regression coefficient 0.335, $P < 0.05$) of ATL on improving AGD in eastern China was greater than that in central and western China. This is mainly due to the economic foundation and infrastructure conditions, the tourism flow, information flow and factor flow in the eastern region can operate conveniently and

TABLE 12 Non-linear test results of the panel smooth transformation model.

Model	Number of positional parameters	H_0: $r=0$; H_1: $r=1$		H_0: $r=1$; H_1: $r=2$	
		LM	LM_F	LM	LM_F
Model 5	$m=1$	19.471***	6.839**	6.914	1.642
	$m=2$	24.404***	4.004**	4.532	0.994
Model 6	$m=1$	14.728**	5.569**	5.674	0.585
	$m=2$	21.303**	6.045**	6.343	0.711
Model 7	$m=1$	15.831***	4.976**	4.056	0.899
	$m=2$	20.882***	4.085*	3.880	0.512
Model 8	$m=1$	13.654***	6.176**	3.154	0.765
	$m=2$	19.764***	4.543*	3.543	0.438

***, **, and * represent $P < 0.01$, $P < 0.05$, and $P < 0.1$ respectively.

efficiently. Therefore, the spillover effect in the eastern region is more prominent.

4.3 Non-linear effect estimation results and analysis

With ATL as the transformation variable, Model 5 to Model 8 were constructed for the whole region, the eastern region, the central region and the western region to test whether there were differences in the influence of the integration level of agriculture and tourism on the improvement of AGD in different regions. Non-linear tests were performed on the models before model estimation (Table 12). When the number of positional parameters $m = 1$ and $m = 2$, all models rejected the null hypothesis that $r = 0$, indicating that the constructed non-linear relationship model was reasonable. According to the principle of panel smooth transfer model, the number of model conversion functions can be obtained as 1, that is, $r = 1$.

Secondly, the conversion mechanism and the number of optimal positional parameters were selected according to AIC and BIC criteria (González et al., 2017). In each model, the number of positional parameters corresponding to the minimum AIC and BIC values is the ideal number of positional parameters. It is verified that the number of positional parameters of each model is 1. On the basis of the above tests, the results of model estimation combined with the data of various provinces over the years are shown in Table 13.

First, for the whole study area, when the conversion function $g(\text{ATL}_{it}; r, c) = 0$, the coefficient of the integrated development of agriculture and tourism is 0.065 (β_{01}), indicating a low-mechanism state. When the conversion function $g(\text{ATL}_{it}; r, c) = 1$, the impact of ATL rises to 0.441 ($\beta_{01} + \beta_{11}$), signifying a high-mechanism state. The influence of this integration on AGD transitions smoothly between these two mechanisms, with a threshold value of 0.723 ($e^{-0.318}$) demarcating the shift from low to high mechanism. As the integration level changes, the effect on AGD gradually increases from 0.065 to 0.441, suggesting that the integration of agriculture and tourism not only contributes to AGD improvement but also enhances its impact as the level of integration increases.

Analyzing the trend in AGD from 2011 to 2021, growth was relatively slow from 2011 to 2013, followed by an acceleration of growth after 2014. Although China had already proposed the vigorous development of rural tourism in 2010, early efforts primarily focused on the simple "farmhouse music" model, resulting in a relatively low level of integration. When the integration level of agriculture and tourism is low, the ecological premium of agriculture is not fully utilized, and agricultural producers pay more attention to the increase of output, and seldom consider the environmental pollution caused by agricultural production and the conscious reduction of the input of harmful environmental factors such as pesticides and fertilizers.

However, as leisure agriculture and rural tourism began to play a more significant role in integrating agricultural functions and rural industries, policy support for industrial integration was significantly strengthened, ATL improved as a result, highlighting its role in promoting AGD. In 2014, eight provinces surpassed the threshold value of 0.730, while by 2019, 18 provinces had crossed this threshold. This trend confirms that ATL has a non-linear effect on AGD improvement: as the level of integration increases, its effect on AGD becomes more pronounced. When the level of agro-tourism integration is high and agro-ecological resources can create more ecological value, agricultural producers will take the initiative to reduce the input of harmful environmental factors in agricultural production, so as to make agro-tourism integration develop in a sustainable direction.

Second, from a regional perspective, in the eastern region, once the level of ATL surpasses the threshold value of 0.693 ($e^{-0.366}$), its impact on AGD steadily increases. Both the linear and non-linear coefficients for the influence of ATL on AGD in this region exceed the national average. This can be attributed to the favorable natural resources and climate conditions in the east, as well as a strong demand for tourism, which stimulates the integrated development of agriculture and tourism. As integration levels rise, the agricultural ecological value becomes more apparent, encouraging agricultural producers to focus on sustainable agricultural practices. This heightened ecological awareness leads to a stronger emphasis on agricultural ecology and a more sustainable development approach, thereby improving AGD. Hence, the effect of ATL on AGD in the eastern region is more substantial than the national average.

In contrast, the western region has the highest threshold, suggesting that overcoming this threshold is more challenging compared to other regions. In this region, only when the threshold value of 0.730 ($e^{-0.314}$) is surpassed does the integration of agriculture and tourism begin to positively influence AGD. This can be explained by the weaker economic foundation and limited access to advanced agricultural technologies in many western provinces. Additionally, the natural resource and climatic conditions in this region are less conducive to the widespread development of agricultural tourism. Consequently, during the early stages of integration, the effect of ATL on AGD is minimal. However, once the threshold value of 0.730 is exceeded, the creation of agro-ecological capital generates more ecological value, prompting agricultural producers to prioritize sustainable development.

TABLE 13 Estimated results of panel smooth transformation model.

	Coefficient	Model 5	Model 6	Model 7	Model 8
Slope parameter	r	1.432	2.769	3.236	3.586
Location parameter	c	−0.318	−0.366	−0.335	−0.314
Linear part coefficient	β_{01}	0.065***	0.072***	0.074***	0.055
	β_{02}	0.110***	0.175***	0.032**	0.072**
	β_{03}	0.003**	0.004**	0.004**	0.002
	β_{04}	0.026*	0.021	0.019**	0.020
	β_{05}	0.052**	0.089**	0.023	0.024
	β_{06}	0.001	0.003	0.002	0.001
	β_{07}	−0.165**	−0.209**	−0.085	−0.089
Non-linear part coefficient	β_{11}	0.376**	0.393**	0.265**	0.236**
	β_{12}	1.191***	0.999**	1.120**	1.035**
	β_{13}	0.024**	0.015	0.005	0.031
	β_{14}	0.139**	0.157**	0.135**	0.111
	β_{15}	0.154**	0.143**	0.185**	0.105**
	β_{16}	0.004***	0.005	0.002	0.002
	β_{17}	−0.318***	−0.353***	−0.299***	−0.275***
Composite coefficient	$\beta_{01}+\beta_{11}$	0.441	0.465	0.339	0.291
	$\beta_{02}+\beta_{12}$	1.301	1.174	1.152	1.107
	$\beta_{03}+\beta_{13}$	0.027	0.019	0.009	0.033
	$\beta_{04}+\beta_{14}$	0.165	0.178	0.154	0.131
	$\beta_{05}+\beta_{15}$	0.206	0.232	0.208	0.129
	$\beta_{06}+\beta_{16}$	0.005	0.008	0.004	0.003
	$\beta_{07}+\beta_{17}$	−0.483	−0.562	−0.384	−0.386

***, **, and * represent $P < 0.01$, $P < 0.05$, and $P < 0.1$ respectively.

As harmful environmental inputs are reduced and agricultural practices become more eco-friendly, AGD begins to improve, and the positive effect of ATL on AGD becomes more significant.

5 Conclusions, limitations, and policy recommendations

5.1 Conclusions

Based on panel data from 30 provinces in China from 2011 to 2022, this study employed fixed effects models, SDM and PSTR model to explore the impact of the integration of agriculture and tourism on agriculture green development (AGD) and its spatial spillover effects and non-linear characteristics. The key findings are as follows:

(1) Over the study period, both agriculture and tourism integration and agricultural green development levels exhibited steady increases, with average annual growth rates of 3.823% and 2.144%, respectively. Overall, agricultural green development and ATL levels in the eastern region were found to be higher than in the central and western regions.

(2) Agriculture and tourism integration has a significant positive effect on agricultural green development. This conclusion is consistent with that of Jiang (2022). Rooted in ecological sustainability and supported by agriculture and rural areas, this integration promotes agricultural intensification and environmentally friendly production management, which in turn contributes to the advancement of agriculture green development.

(3) The impact of agriculture and tourism integration on agricultural green development reveals substantial spillover effects. The agriculture and tourism integration coefficient in the fixed effects model is higher than that in the spatial effects model, suggesting that neglecting spatial spillover effects may lead to an overestimation of the positive impact of agriculture and tourism integration. The estimation results across the eastern, central, and western regions align with those for the entire study area: agriculture and tourism integration has both direct (local) and spatial spillover effects on agricultural green development. Notably, the direct effects are stronger in the central and western regions, while the spillover effects are more pronounced in the eastern region.

(4) The relationship between agriculture and tourism integration and agricultural green development is non-linear, with a single threshold value identified in the whole region and across the three regions. This conclusion is different from the study of Wang et al. (2024a,b), whose study showed a double threshold effect of agriculture and tourism integration on agricultural eco-efficiency, and this difference may be due to the different scale of the study area. When agriculture and tourism integration exceeds this threshold in the study area, the regression coefficient for agriculture and tourism integration increases, indicating that higher levels of integration positively influence agricultural green development. Among the three regions, the eastern region has the lowest threshold value, whereas the western region has the highest. In western China, the effect of agriculture and tourism integration on agricultural green development does not pass the significance test until it crosses this threshold. This finding suggests that enhancing the integration of agriculture and tourism is key to fully leveraging its potential to promote green agricultural development.

5.2 Limitations

Although this paper demonstrates the impact of the integration of agriculture and tourism on the green development of agriculture through quantitative models, and analyzes its non-linear characteristics and spillover effects, it still has the following shortcomings: First, although the impact mechanism is theoretically analyzed in this paper, the empirical test of the mechanism is not carried out, and the impact mechanism can be further tested through empirical analysis in the future; Second, limited to the availability of data, this paper uses provincial panel data for research, and the spatial scale of sample measurement is large, so the accuracy of the results may be affected. In the future, the quantitative analysis can be carried out through smaller scale sample data such as municipal panel data.

5.3 Policy recommendations

The findings of this study provide valuable insights for promoting the integration of agriculture and tourism and maximizing its role in fostering agriculture green development:

(1) Optimize and Improve Policy Framework and Strategic Design

The integration of agriculture and tourism needs strong support and scientific planning from the government. It is important to coordinate short-term planning and long-term planning while scientifically evaluating the development potential of the integration of agriculture and tourism and the environmental carrying capacity of each region. This ensures the rationality and feasibility of the project development. The integrated development of agriculture and tourism in different regions should give full play to local resource endowments and actively explore an integrated development model based on ecological protection such as sustainable use of mountains, rivers and lakes.

To play a leading role, the government should focus on expanding the depth and breadth of the agricultural value chain and building a modern agricultural industrial system. At the same time, the government should increase financial investment in the project of integrating agriculture and tourism, and ensure that the funds are used for infrastructure construction, environmental improvement, cultural excavation and inheritance. By setting up special funds or providing financial subsidies, the investment threshold and risk of agricultural and tourism integration projects will be reduced. Enterprises and individuals engaged in agricultural and tourism integration projects will be given tax incentives to reduce operating costs and improve profitability. In addition, it is necessary to establish a scientific and reasonable performance evaluation index system to comprehensively evaluate the economic benefits, social benefits and ecological benefits of agricultural and tourism integration projects to ensure the sustainable development of industrial integration.

(2) Promote Regional Coordination Mechanisms for Development

On the first hand, the government should introduce relevant policies to encourage and support cross-regional cooperation on the integration of agriculture and tourism, such as providing tax incentives, financial support and land policy inclining, so as to reduce cooperation costs and improve cooperation benefits. Establish a cross-regional coordination organization for the integration of agriculture and tourism, which is responsible for overall planning and coordinating resources of all parties, and solve the problems of cross-responsibility and poor coordination among departments. On the other hand, increase the investment in trans-regional transport infrastructure, improve the capacity and comfort of roads, and ensure that tourists can easily reach each rural and tourism integration area. Meanwhile, we should integrate agricultural resources in different regions through cross-regional cooperation to form scale effects and complementary advantages.

(3) Strengthen and Prioritize Human Capital Development

Advancing the integration of agriculture and tourism requires the support of a highly skilled workforce. Policies and initiatives should be designed to attract and nurture talent in line with the specific needs of agriculture and tourism integration and industrial development. Special attention should be given to developing foundational technical skills, as well as middle- and senior-level management and operational expertise. In addition, rural vocational and technical education should be strengthened to improve agricultural techniques and enhance the professional skills of local workers, thereby elevating the quality of rural tourism services.

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

CC: Conceptualization, Data curation, Investigation, Software, Writing – original draft. JW: Formal analysis, Project administration, Supervision, Writing – review & editing. WJ: Conceptualization, Formal analysis, Investigation, Supervision, Validation, Writing – original draft. AX: Resources, Software, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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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

Amsden, B., and McEntee, J. (2011). Agri-leisure: re-imagining the relationship between agriculture, leisure and social change. *Leisure/Loisir* 35, 37–48. doi: 10.1080/14927713.2011.549194

Arru, B., Furesi, R., Madau, F. A., and Pulina, P. (2019). Recreational services provision and farm diversification: a technical efficiency analysis on Italian agritourism. *Agriculture* 9:42. doi: 10.3390/agriculture9020042

Ayyildiz, A. Y., and Koc, E. (2024). "Promotion of agritourism as a sustainable form of tourism," *Rethinking Sustainable Tourism in Geographical Environments: Theory and Practices* (Berlin: Springer), 209–219.

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. Agricult. Res. Econ.* 63, 521–548. doi: 10.1111/1467-8489.12304

Chen, X., and Chen, Z. (2021). Can China's environmental regulations effectively reduce pollution emissions? *Int. J. Environ. Res. Public Health* 18:4658. doi: 10.3390/ijerph18094658

Collins, L., Hill-Sullins, N., and Ellis Ph, D. J., and Cozma, R. (2024). Exploring the determinants of agritourism business owners' expansion intention. *J. Appl. Commun.* 108:4. doi: 10.4148/1051-0834.2528

Elhorst, J. P. (2003). Specification and estimation of spatial panel data models. *Int. Reg. Sci. Rev.*, 26, 244–268. doi: 10.1177/0160017603253791

Fleischer, A., and Tchetchik, A. (2005). Does rural tourism benefit from agriculture? *Tour. Manag.* 26, 493–501. doi: 10.1016/j.tourman.2003.10.003

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

Gao, J., and Wu, B. (2017). Revitalizing traditional villages through rural tourism: a case study of Yuanjia Village, Shaanxi Province, China. *Tour. Manag.* 63, 223–233. doi: 10.1016/j.tourman.2017.04.003

Ge, P., Liu, T., Wu, X., and Huang, X. (2023). Heterogenous urbanization and agricultural green development efficiency: evidence from China. *Sustainability* 15, 1–22. doi: 10.3390/su15075682

González, A., Teräsvirta, T., and Dijk, D. V. (2005). "Panel smooth transition regression models," *SEE/EFI Working Paper Series in Economics and Finance, vol. 2* (Uppsala: Uppsala University), 604.

González, A., Teräsvirta, T., Dijk, D. V., and Yang, Y. (2017). "Panel smooth transition regression models," *CREATES Research Papers 2017-36, Department of Economics and Business Economics*. Aarhus: Aarhus University.

Grillini, G., Streifeneder, T., Stotten, R., Schermer, M., and Fischer, C. (2025). How tourists change farms: the impact of agritourism on organic farming adoption and local community interaction in the Tyrol-Trentino Mountain region. *J. Rural Stud.* 114:103531. doi: 10.1016/j.jrurstud.2024.103531

Guo, H., Gu, F., Peng, Y., Deng, X., and Guo, L. (2022). Does digital inclusive finance effectively promote agricultural green development? A case study of China. *Int. J. Environ. Res. Public Health* 19:6982. doi: 10.3390/ijerph19126982

Hall, B., and Kerr, M. (1991). *Green index: A State-by-State Guide to the Nations Environmental Health*. Washington, DC: Island Press.

He, Y., and Liu, G. (2022). Coupling coordination analysis of low-carbon development, technology innovation, and new urbanization: data from 30 provinces and cities in China. *Front. Publ. Health* 10:1047691. doi: 10.3389/fpubh.2022.1047691

He, K., Li, F., and Zhang, J. (2021). Green development levels and regional differences of agriculture in the Yangtze River Economic Belt. *J. Huazhong Agric. Univ.* 40, 43–51. doi: 10.13300/j.cnki.hnlkxb.2021.03.006

Hou, D., and Wang, X. (2022). Inhibition or promotion?—The effect of agricultural insurance on agricultural green development. *Front. Public Health* 10, 1–15. doi: 10.3389/fpubh.2022.910534

Huang, C. M., Tuan, C. L., and Wongchai, A. (2014). Development analysis of leisure agriculture—A case study of Longjing Tea Garden, Hangzhou, China. *APCBEE Procedia* 8, 210–215. doi: 10.1016/j.apcbee.2014.03.029

Huang, Y. Z., Luo, X. F., and Li, Z. L. (2017). Analysis on spatial-temporal differences and influences factors of agricultural green production level in China. *J. China Agric. Univ.* 22, 183–190. doi: 10.11841/j.issn.1007-4333.2017.10.23

Jiang, G. (2022). How does agro-tourism integration influence the rebound effect of China's agricultural eco-efficiency? An economic development perspective. *Front. Environ. Sci.* 10, 1–13. doi: 10.3389/fenvs.2022.921103

Joo, H., Khanal, A. R., and Mishra, A. K. (2013). Farmers' participation in agritourism: does it affect the bottom line? *Agric. Res. Econ. Rev.* 42, 471–490. doi: 10.1017/S1068280500004949

Kaswanto (2015). Land suitability for agrotourism through agriculture, tourism, Beautification and Amenity (ATBA) Method. *Procedia Environ. Sci.* 24, 35–38. doi: 10.1016/j.proenv.2015.03.006

LaPan, C., and Xu, S. (2024). Pluralities of agritourism: exploring political values and social judgements. *J. Rural Stud.* 111:103395. doi: 10.1016/j.jrurstud.2024.103395

Li, F., Zhou, X., and Zhou, Y. (2023). Evaluation and regional difference analysis of agricultural green development level in Bohai Rim Region. *Chin. J. Agric. Resour. Reg. Plann.* 44, 118–129. doi: 10.7621/cjarrp.1005-9121,20230313

Li, J., and Li, Y. (2019). Influence measurement of rapid urbanization on agricultural production factors based on provincial panel data. *Socioecon. Plann. Sci.* 67, 69–77. doi: 10.1016/j.seps.2018.09.004

Li, X., and Guan, R. (2023). How does agricultural mechanization service affect agricultural green transformation in China? *Int. J. Environ. Res. Public Health* 20:1655. doi: 10.3390/ijerph20021655

Liu, Y., Sun, D., Wang, H., Wang, X., Yu, G., Zhao, X., et al. (2020). An evaluation of China's agricultural green production: 1978–2017. *J. Clean. Prod.* 243:118483. doi: 10.1016/j.jclepro.2019.118483

Lu, Y., Wang, L., and Zhou, Z. (2024). A study on the coupling coordination degree and temporal and spatial evolution of China's agricultural green development level and agricultural science and technology innovation capability. *Agricult. Econ. Manage.* 4, 90–104. doi: 10.3969/j.issn.1674-9189.2024.04.008

Luo, J., Huang, M., and Bai, Y. (2024). Promoting green development of agriculture based on low-carbon policies and green preferences: an evolutionary game analysis. *Environ. Dev. Sustain.* 26, 6443–6470. doi: 10.1007/s10668-023-02970-2

Luo, M. Z., and Wei, B. H. (2022). Analysis of environmental effect of rural industry integration. *Rural Eco.* 57–66.

Madaleno, A., Eusébio, C., and Varum, C. (2019). The promotion of local agro-food products through tourism: a segmentation analysis. *Curr. Issues Tour.* 22, 643–663. doi: 10.1080/13683500.2017.1296417

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

Oenema, O. (2020). Toward agriculture green development. *Front. Agricult. Sci. Eng.* 7, 110–111. doi: 10.15302/J-FASE-2019314

Renting, H., Rossing, W. A. H., Groot, J. C. J., Van der Ploeg, J. D., Laurent, C., Perraud, D., et al. (2009). Exploring multifunctional agriculture. A review of conceptual approaches and prospects for an integrative transitional framework. *J. Environ. Manage.* 90, S112–S123. doi: 10.1016/j.jenvman.2008.11.014

Rogerson, C. M. (2012). Strengthening agriculture-tourism linkages in the developing World: opportunities, barriers and current initiatives. *Afr. J. Agricult. Res.* 7, 616–623. doi: 10.5897/AJARX11.046

Schilling, B., Sullivan, K., and Komar, S. (2012). Examining the economic benefits of agritourism: the case of New Jersey. *J. Agric. Food Syst. Commun. Develop.* 3, 199–214. doi: 10.5304/jafscd.2012.031.011

Schmidt-Traub, G. (2020). The urgency of agriculture green development. *Front. Agricult. Sci. Eng.* 7, 108–109. doi: 10.15302/J-FASE-2019313

Soleimannejad, R., Alibaygi, A., and Salehi, L. (2021). Barriers and facilitators of agri-tourism sustainable development in west of Mazandaran Province. *Geogr. Environ. Plann.* 33, 1–4.

Streifeneder, T. (2016). Agriculture first: assessing European policies and scientific typologies to define authentic agritourism and differentiate it from countryside tourism. *Tour. Manage. Perspect.* 20, 251–264. doi: 10.1016/j.tmp.2016.10.003

Su, Y. W. (2020). Measurement of the integration level of Producer services and manufacturing: based on the provincial panel data from 2005 to 2018. *Macro Econ. Res.* 12, 98–108. doi: 10.16304/j.cnki.11-3952/f.2020.12.010

Sun, Y. (2022). Environmental regulation, agricultural green technology innovation, and agricultural green total factor productivity. *Front. Environ. Sci.* 10, 1–13. doi: 10.3389/fenvs.2022.955954

Valdivia, C., and Barbieri, C. (2014). Agritourism as a sustainable adaptation strategy to climate change in the Andean Altiplano. *Tour. Manage. Perspect.* 11, 18–25. doi: 10.1016/j.tmp.2014.02.004

Wang, J., Xia, L., Zhou, F., Chen, C., and Zhu, Q. (2023). Impacts of the integrated development of agriculture and tourism on sustainable development of agriculture—Based on provincial data of China from 2008 to 2019. *Polish J. Environ. Stud.* 32, 3825–3843. doi: 10.15244/pjoes/163566

Wang, J., Yang, G., and Zhou, C. (2024a). Does internet use promote agricultural green development? Evidence from China. *Int. Rev. Econ. Fin.* 93, 98–111. doi: 10.1016/j.iref.2024.03.009

Wang, J., Zhou, F., Xie, A., and Shi, J. (2024b). 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, J., and Zhou, F. (2021). The effect of integrated development of agriculture and tourism on agricultural ecological efficiency. *J. Hunan Agricult. Univ. (Social Science Edition),* 22, 50–56. doi: 10.13331/j.cnki.jhau(ss).2021.02.007

Wang, L. F. (2018). The Dynamic Mechanism and Development Path for Integration of Agriculture and Tourism in Shanxi Province. *J. Agro-Tech. Econ.* 4, 136–144. doi: 10.13246/j.cnki.jae.2018.04.012

Xiong, W., and Zhou, P. (2024). Evaluation of agricultural green development level and analysis on spatial-temporal differences in the Yangtze River Basin. *Ecol. Econ.* 40, 119–128.

Yang, Y. H., He, J. X., Zhang, X. H., and Rui, Y. (2023). Spatial differentiation characteristics and influencing texture of the coupling coordinated development of agro-culture-tourism in China. *Arid Geogr. Land* 46, 448–59. doi: 10.12118/j.issn.1000–6060.2022.295

Zhang, H., Zhang, J., and Song, J. (2022). Analysis of the threshold effect of agricultural industrial agglomeration and industrial structure upgrading on sustainable agricultural development in China. *J. Clean. Prod.* 341:130818. doi: 10.1016/j.jclepro.2022.130818

Zhang, N., Zhang, L., and Zhao, H. et al. (2018). Construction and application of evaluation index system for agricultural green development. *Ecol. Econ.* 34,21–24.

Zhao, H., and Yu, F. (2019). Evaluation of agricultural green development level in main-grain producing areas based on entropy method, *Reform* 11, 136–146.

Zhong, Y., Tang, L., and Li, Y. (2022). Role of digital empowerment in developing farmers' green production by agro-tourism integration in Xichong, Sichuan. *Agriculture* 12, 1–18. doi: 10.3390/agriculture12111761

Zhou, X., Chen, T., and Zhang, B. (2023). Research on the impact of digital agriculture development on agricultural green total factor productivity. *Land* 12:195. doi: 10.3390/land12010195