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Spatiotemporal Distribution and Influencing Factors of Coupling Coordination between Digital Village and Green and High-Quality Agricultural Development—Evidence from China

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Abstract: With digital technologies injecting a strong impetus into China's sustainable agricultural development, the digital village is a new path for Chinese agricultural development. This paper focuses on digital village and sustainable agricultural development, in which the situation of digital village and green and high-quality agricultural development in China from 2010 to 2019 is measured based on the entropy weight–TOPSIS method and coupling coordination model and further explores the spatiotemporal evolution of their coupling coordination. In addition, it studies the factors which influence the coupling coordination of digital village and green and high-quality agricultural development using a geographical detector. The study shows that both digital villages and green and high-quality agricultural development in China show good momentum. In terms of the spatial pattern, cities on the southeast coast witness better development of digital villages, and the southern regions enjoy a higher degree of green and high-quality development in agriculture. The coupling coordination between digital villages and green and high-quality agricultural development shows a fluctuating upward trend in the eastern regions. Some of the influence factors play a significant role in the coupling coordination of digital villages and green and high-quality agricultural development, such as e-commerce, per capita income, innovation, and levels of income and education. On this basis, we suggest that the government should continuously promote the development of digital villages and improve rural governance to bridge the digital divide. In this case, policies to promote green and high-quality agricultural development through digitalization can be introduced according to local conditions, thus enabling sustainable agricultural development with the empowerment of digitalization.

Keywords: digital village; green total factor productivity; coupling coordination; driving factors; modernization of rural governance

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1. Introduction

With 8% of the world's arable land, China supports 20% of the world's population depending on agriculture and provides sufficient production factors and raw materials for our growing economy. It also contributes to the remarkable achievements made in the national strategy of all-round poverty alleviation and rural revitalization [1]. However, the traditional agricultural production pattern, which excessively emphasizes output and the use of chemical elements, has caused ecological and environmental problems that cannot be ignored and further threatened sustainable agricultural development [2,3]. In order to promote green production and high-quality agricultural development, the Chinese government has recently pursued supply-side structural reform as the main task to achieve agricultural transformation from extensive development to promote total factor productivity development. It is also making efforts to improve the quality of agricultural production factors, promote the transformation of agricultural growth momentum, and realize innovation-driven and high-quality development. From an academic point of view, new momentum that promotes agricultural total factor productivity is urgently needed to solve the increasingly serious agricultural environmental problems. Moreover, academics have become increasingly focused on how to achieve agricultural transformation from the traditional pattern with a high input of production factors to the new pattern that is driven by digitalization and green and high-quality development [4].

Since the 21st century, digital transformation has spread to all countries in the world, especially China, which is experiencing the rapid development of its digital economy. By June 2022, there were 1.051 billion netizens in China, with a 74.4% Internet penetration rate and 58.8% of that in rural areas. (Data obtained from *The 50th Statistical Report on the Development Status of the Internet in China*, China Internet Network Information Center, http://www.cnnic.net.cn/n4/2022/0914/c88-10226.html, accessed on 31 August 2022). The *DIGITAL ECONOMY REPORT 2021 (Cross-border data flows and development: For whom the data flow*), issued by the United Nations, indicates that China and the United States stand out as the strongest participants in and beneficiaries of the digital economy, with half of the world's hyperscale data centers based in China and the United States, both of which enjoy the highest 5G penetration rates across the world (source of information: Digital Economy Report 2021 (Cross-border data flows and development: For whom the data flow), https://unctad.org/page/digital-economy-report-2021, accessed on 29 September 2021). As of 2020, the value added by the digital economy in China was roughly valued at CNY 39.2 trillion, with a 38.6% increase in the proportion of GDP [5]. In 2018, the Chinese government initially proposed to "implement the digital village strategy", with the intention of improving agricultural production through the application of digital technology, enhancing agricultural production efficiency, and upgrading the level of rural governance. Thereafter, the *China 14th Five-Year Development Plan*, which was introduced in 2021, also suggested that the Chinese government would advance the digital transformation of the social economy as an essential creed for national development, vigorously facilitate the development of the digital economy, conduct all-round and whole-chain transformation and upgrading of traditional industries, such as agriculture, by employing new Internet technologies, and enhance the total factor productivity of agriculture to exert the leading role of the digital economy and digital technology on the development of the traditional economy.

The digital economy was initially coined by Tapscott in 1996, who considered the digital economy as a new form of economy on the basis of new Internet technologies to drive the networking of human intelligence [6]. Afterward, scholars progressively commenced to undertake a joint exploration of the digital economy and the development of agricultural modernization, with the main focus on digital transformation facilitating sustainable agricultural development [7], information and communication technology empowering the digital development of Indian agriculture [8], as well as the contribution of information and communication technology development to improve the efficiency of agricultural production in developing countries [9]. In the meantime, there were also scholars who focused on intelligent agricultural technologies and digital governance practices in agriculture [10], the development of information technology to bridge the urban–rural development divide in South Korea [11], the impact of digital technology on various stakeholders in agriculture [12], as well as digital finance to facilitate rural household agricultural production [13]. The available studies provided significant insights into the relationship between the digital economy and high-quality agricultural development for this paper. Nevertheless, after reviewing the available studies, it was also revealed that the research on digital village and high-quality agricultural development is still in its exploration stage. Moreover, most of the studies were concerned with the design of a digital village indicator system [14], digital village governance issues [15,16], the facilitating role of digital development in sustainable agricultural rural development [17], as well as strategies for advancing the digital transformation of agricultural rural areas [18,19]. Meanwhile, there also remains a number of deficiencies in the available studies. The first lies in the insufficient research on the functional relationship between digital village and high-quality agricultural development, with few studies incorporating both of them into the research framework, which has neglected the synergistic evolutionary characteristics of digital village and high-quality agricultural development. As a consequence, few studies have been conducted on the driving mechanism of coupling coordination between digital village and high-quality agricultural development. The second lies in the fact that the available studies have largely focused on the impact of digitalization or Internet use on agricultural production methods and output from the perspective of microfarmers but less from the macroprovincial scale to conduct research on digital village and high-quality agricultural development. The exploration of driving mechanisms on this basis is instrumental in providing academic support for policy formulation at a macro level.

On the basis of the above reasons, this paper elaborated the connotation of the concepts of digital village and high-quality agricultural development in a systematic manner, while analyzing in depth the inner mechanism of the coupling coordination between digital village and high-quality agricultural development. Furthermore, by taking China as a further instance, this paper verified the inner coordination mechanism between the two through quantitative analysis of the spatiotemporal differentiation characteristics and their influencing factors regarding the development of the coupling coordination between the two. To be specific, the digital village indicator system was first constructed and the entropy weight–TOPISIS method was adopted to conduct quantitative assessment and analysis of the digital village level at the provincial level in China, while the SBM model was adopted to calculate the green total factor productivity of Chinese agriculture. Secondly, the inter-relationship between the two was probed using a coupling coordination relative development model, which dissected the current nonsynergistic phenomena in the interaction process between the digital economy and high-quality agricultural development in China. Lastly, the geographical detector model was employed to analyze the influencing factors affecting the spatiotemporal distribution pattern of the coupling between the two. This paper aims to deliver scientific references and beneficial suggestions to facilitate the construction of digital villages and boost sustainable agricultural development through the theoretical construction and empirical analysis of the relationship between digital village and high-quality agricultural development.

2. Coupling Analysis between Digital Village and High-Quality Agricultural Development

Following the in-depth development of the digital economy, the construction of digital villages has received increasingly more attention from scholars, while the connotation of the digital village has not yet been explicitly defined by academics [20–22]. The EU defines the digital village as a process of utilizing digital communication technologies to creatively reinforce traditional networks and construct new information networks on the basis of available resource advantages and rural assets and establish new models of urban–rural interaction, thereby introducing new development opportunities for rural areas (source of information: Smart Villages, European Commission, https://digitevent-images.s3.amazonaws.com/5c0e6198801d2065233ff996-registrationfiletexteditor-1551115459927-smart-villages-briefing-note.pdf, accessed on 22 February 2019). Sutriadi considered the digital village as a new form to achieve the sustainable and innovative development of urban and rural areas by enhancing rural human capital and applying information and communication technologies for the efficient development of various parts of the village with the support of the national development planning system [23]. On this basis, this paper views the digital village as a new development model that aims at achieving high-quality agricultural development and modernized rural development, with digital technology as a tool to carry out the digital reconstruction of agriculture, production, life, ecology, culture, and the organization of rural areas [24,25].

High-quality agricultural development refers to the new development requirements put forward by the central government for agriculture following the entry of China's economic development into a new normal. (The State Council of the Central Committee of the Communist Party of China issued the *Strategic Plan for Rural Revitalization (2018–2022)*, http://www.gov.cn/zhengce/2018-09/26/content_5325534.htm, accessed on 26 September 2018). This paper argues that high-quality agricultural development typically refers to the process of the overall improvement in agricultural development with emphasis on the quality of agricultural products, agricultural production efficiency, per capita income of farmers, and green and sustainable agricultural development [26,27]. High-quality agricultural development should also be an organic whole that involves the modernization of the agricultural industrial system, production system, and operation system in all aspects. The industrial system serves as the top-level structural design of high-quality agricultural development, and the production system is the power source of high-quality agricultural development, while the operation system acts as the operational guarantee of high-quality agricultural development [28,29].

In 1977, the German scholar Haken first proposed the synergetic theory [30], which unveils the coordination relationship in which complex systems and multiple systems interact and cooperate with each other [31]. From the viewpoint of synergetic theory, there exists an inextricable link between the digital village and high-quality agricultural development. On the one hand, the digital village introduces advanced agricultural digital technology, an organizational model, and a business system, which, in turn, facilitates high-quality agricultural development [32]. On the other hand, high-quality agricultural development furnishes directional guidance and experiential reference for the construction of the digital village [29,33]. For the sake of advancing the coupling coordination between digital village and high-quality agricultural development, it is imperative to take into account the holistic development law of the village, respect the natural resource endowment and human capital level of the village, refine the digital infrastructure, and integrate the relationship between various elements and links of the agricultural industry by focusing on the application of digital technology and the digital transformation of the rural industry. In this way, a green, healthy, and efficient agricultural industrial system can be constructed on the basis of modern agricultural industrial development to optimize the structure of agricultural inputs and outputs and minimize agricultural surface source pollution [34,35]. In the meantime, the "livestream commerce" and other industrial business forms derived from the new rural business model support the reconstruction of the agricultural industry chain and value chain and the realization of the coordination between the digital countryside and high-quality agricultural development, thereby heading for a new stage of sustainable development at a higher level [36]. In this context, it is evident that the digital village and the high-quality agricultural development are mutually influencing, with mutual interaction and promotion. The realization of the coupling coordination between the two can not only optimize the allocation of factor resources and enhance the efficiency of agricultural production but also boost sustainable agricultural development and realize green and high-quality development. The overall research framework of the article is conceived as shown in Figure 1.

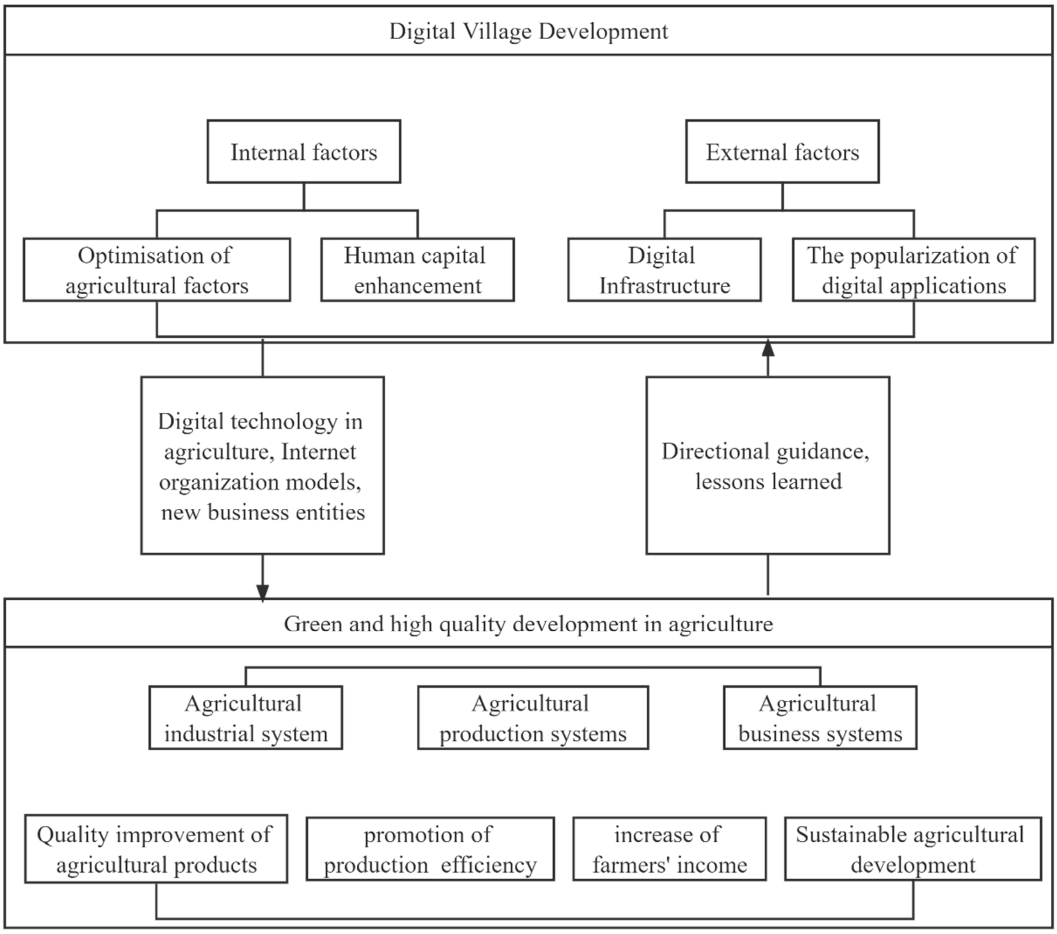

Figure 1. Logical framework diagram.

3. Research Methods

With a view to exploring the spatiotemporal coupling coordination characteristics of the digital village and high-quality agricultural development in China, this study further guides the construction of the digital village and facilitates sustainable agricultural development. First and foremost, this study selected three dimensions of digital infrastructure, human capital, and digital application level of rural industries and calculated the level of digital village development in China by adopting the entropy weight–TOPSIS method. Meanwhile, the total nitrogen pollution from agricultural fertilizers, total phosphorus pollution, and agricultural carbon emissions were considered as nonexpected outputs, while the green total factor productivity of Chinese agriculture was calculated using SBM model. Secondly, the coupling coordination degree model was employed to investigate the spatiotemporal characteristics of the coupling coordination between digital village and high-quality agricultural development. Lastly, factor detection and interaction detection methods of the geographical detector model were employed to analyze the influencing factors affecting the spatiotemporal distribution pattern of the coupled coordination between the two.

3.1. Construction of the Indicator System

3.1.1. Construction of the Digital Village Indicator System

In accordance with the connotation of the concept of digital village and with reference to relevant research results [21,37], this paper selected 3 second-level indicators, including digital infrastructure, human capital, and digitalization level of rural industry, which followed systematization, science, and operability, while constructing a comprehensive evaluation indicator system of digital village as shown in Table 1.

Table 1. Evaluation Indicator System of Digital Village.

Indicators	Type of Indicators	Content of Indicators
Digital Village	Digital Infrastructure	Number of Postal Outlets (Branch) Telephone Penetration Rate (%) Length of Optical Fiber Cable (KM) Number of 3G Mobile Phones (Ten Thousand Households) Number of Internet Broadband Access Ports (Million) Number of Broadband Access Users (Ten Thousand Households)
	Human Capital	Number of Students Enrolled in Higher Education Institutions (People) Average Number of Students Enrolled in Higher Education Institutions Per 100,000 Population (People)
	Digitalization of Rural Industries	Total Post and Telecommunications Business (CNY100 mn) Express Business Volume (Ten Thousand Pieces) Freight Volume (Ten Thousand Tons) Number of Taobao Villages (Place)

Digital infrastructure serves as a prerequisite and support for the development of digital village, which is also an essential indicator to measure the level and potential of digital village construction. Digital infrastructure represents a significant cornerstone of digital village development, which primarily covers the construction of network and information infrastructure and the popularity of digital services in rural areas. Digital infrastructure exerts a critical role in the development of digital villages. In view of this, this paper selected the number of postal outlets, telephone penetration rate, and length of optical fiber cable as digital infrastructure, as well as the number of 3G mobile phones, the number of Internet broadband access ports, and the number of broadband access users as the metrics to measure the level of digital application in rural areas [38,39].

Human capital stands out as a vital foundation for the utilization of digital rural infrastructure, as well as a leading force in revitalizing rural data resources and achieving digitalization of rural industries and rural governance. Taking into account the fact that the current teaching system of higher education in China has already adopted the enhancement of digital literacy and innovation capability of college students as a key cultivation objective and policies are issued jointly by local governments to support the development of rural talents in accordance with the strategy of "rural revitalization", this paper selected the number of students enrolled in higher education institutions, as well as the average number of students enrolled in higher education institutions per 100,000 population, as the metrics of digital talent resources [40].

The advancement of the digitalization of rural industries serves as the core content of digital village construction. To be specific, it refers to the promotion of the speedy development of rural industries represented by rural e-commerce and smart agriculture through the development of rural human resources and the introduction of advanced technical equipment, organizational models, and business systems on the basis of the construction of digital technology facilities. In view of data availability, this paper selected four indicators, namely total business value of post and telecommunications, express business volume, freight volume, and number of Taobao villages to measure the digitalization level of rural industries [41].

3.1.2. Measurement of Green Total Factor Productivity in Agriculture

The green total factor productivity (Green TFP) in agriculture is capable of combining the analysis of agricultural production efficiency with resource use and environmental pollution in an effective manner, which can serve as an essential measurement indicator for green and high-quality agricultural development. Referring to the existing research of scholars [42–44], this paper adopts agricultural labor, land, fertilizers, pesticides, agricultural machinery, and irrigation as input indicators and the total agricultural output value as desired output, while it regards the total nitrogen and total phosphorus pollution in agricultural pollution, as well as carbon emission in farming operations, as nondesired output indicators [45]. Specific indicators are shown in Table 2. In this study, the GML indicator based on the SBM model was employed to calculate the agricultural green total factor productivity using MaxDEA Ultra 9 software.

Table 2. Measurement System of Green Total Factor Productivity in Agriculture.

First-Level Indicators	Second-Level Indicators	Calculation Formulas
Input Indicators	Agricultural Labor Inputs	Agriculture, Forestry, Animal Husbandry, and Fishery Workers (Ten Thousand People)
	Land Inputs	Crop Seeding Area (Thousand Hectares)
	Fertilizer Inputs	Consumption of Agricultural Fertilizers Converted into Purification (Ten Thousand Tons)
	Agricultural Machinery Inputs	Total Power of Agricultural Machinery (Ten Thousand kWh)
	Pesticide Inputs	Amount of Pesticide Used (Ten Thousand Tons)
	Agricultural Water Resources Inputs	Effective Irrigated Area (Thousand Hectares)
Desired Output	Total Agricultural Output	Total Output Value of Agriculture, Forestry, Animal Husbandry, and Fishery (Constant Price from 2000 CNY100 mn)
Nondesired Output	Total Nitrogen Pollution from Agricultural Fertilizers (TN)	Calculation of Total Nitrogen Pollution in Nitrogen Fertilizer and Compound Fertilizer Using Fertilizer Loss Coefficient Method (Ten Thousand Tons)
	Total Phosphorus Pollution from Agricultural Fertilizers (TP)	Calculation of Total Phosphorus Pollution in Phosphate Fertilizer and Compound Fertilizer using Fertilizer Loss Coefficient Method (Ten Thousand Tons)
	Agricultural Carbon Emissions	Carbon Emissions in Fertilizer, Pesticides, Agricultural Film, Diesel, Tillage, Irrigation Agronomic Practices (Ten Thousand Tons)

In this paper, a method of comprehensive survey evaluation and inventory analysis based on the unit were adopted to calculate the agricultural fertilizer surface source pollution accounting units represented by nitrogen, phosphorus, and compound fertilizers, while the loss coefficient method was adopted to measure total emissions of total nitrogen and total phosphorus [46], using the following formula:

$$E = \sum_i Eu_i \times \rho_i \times C_i$$

Therein, E denotes the total emissions of fertilizer surface source pollution, Eu_i denotes the indicator statistics of pollution unit i, which refers to the converted amount of nitrogen, phosphorus, and compound fertilizer application into purification, ρ_i denotes the product coefficient of pollution unit i, C_i denotes the pollution emission coefficient of product unit, while the coefficients were determined in this paper by referring to the studies of Lei [47] and Liang [48].

In this paper, the carbon emissions of each aspect of the farming operation were further measured using the following formula:

$$E = \sum_i E_i = \sum_i T_i \times \delta_i$$

Therein, E denotes total agricultural carbon emissions, E_i denotes carbon emissions per unit carbon source, T_i denotes the statistics of each carbon emission source, while δ_i denotes the corresponding carbon emission coefficients, which were determined in accordance with the study of Li [49].

3.2. Entropy Weight–TOPSIS Method

In this study, the entropy weight–TOPSIS method was employed to evaluate the constructed agricultural ecology and digitalization index system. This method synthesizes the entropy method in the objective weighting method with the TOPSIS method of evaluation of its strength and weakness, which can not only reflect the degree of influence of the variables on the synthesis results in an objective and realistic manner but also perform ranking in accordance with the degree of approximation of the evaluation object to the idealized target. It is unaffected by the sample size and the choice of reference series [50–52], with the specific calculation method referenced in [4].

3.3. Coupling Coordination Model

In this study, the coupling coordination model [53–55] was employed to portray the degree of interaction and mutual influence between the digital village and agricultural GTFP systems, using the following formula:

$$C = \left[\frac{f_{digital}(x) f_{green}(x)}{\left(\left(f_{digital}(x) + f_{green}(x) \right) /2 \right)^2} \right]^{1/2}$$

$$D = \sqrt{C \times (\alpha f_{digital}(x) + \beta f_{green}(x))}$$

In the formula, C denotes the coupling degree score, D denotes the coupling coordination degree score, $f_{digital}(x)$ and $f_{green}(x)$ denote the comprehensive evaluation scores of digital village and agricultural GTFP, respectively, while α and β denote the pending coefficients of digitalization score and high-quality agricultural development level score, where the coupling degree C and coupling coordination degree D both take values in the range of [0, 1]. On the basis of the theory and coupling analysis related to digital village and agricultural high-quality development, this paper concludes that the level of digital agricultural development and high-quality agricultural development are equally significant to the development of agricultural modernization in China, thereby determining the pending coefficient as $\alpha = \beta = 0.5$.

The magnitude of coupling degree C can demonstrate the degree of interaction between subsystems, and the larger the value indicates the stronger the interaction and mutual influence between subsystems. With reference to the study of [54] on the division of coupling degree coefficient, the coupling degree C is classified into low coupling period, antagonistic stage, grinding stage, and coordinated coupling stage with 0.3, 0.5, and 0.8 as the critical points. The coupling coordination degree D is capable of characterizing the degree of coordination in which the two subsystems are situated, with a larger D indicating a higher level of coordination between the subsystems, while the D is close to 1, suggesting that the closer the subsystems are to the state of high-quality coordination. For the sake of hierarchical and graded representation of the coupling coordination degree of digital village and high-quality agricultural development level in China, in conjunction with the analysis data of each subsystem, the coupling coordination development status of digital village and high-quality agricultural development level in China is categorized into 3 stages with 9 types, while the specific classification criteria are shown in Table 3.

Table 3. Classification Criteria of Coupling Coordination Level for Sustainable Development.

Degree of Coupling	Degree of Coupling Coordination	Type	Characteristics	Developmental Stages
$0.3 \leq D \leq 0.5$	$0 \leq D \leq 0.3$	I	The development of digital villages is lagging behind the level of high-quality agricultural development, with the system degraded	Antagonistic Stage
		II	Digital village and the level of high-quality agricultural development facilitate each other, with synchronized development and optimized system	
		III	The level of high-quality agricultural development is lagging behind the digital village, with the system degraded	

Table 3. *Cont.*

Degree of Coupling	Degree of Coupling Coordination	Type	Characteristics	Developmental Stages
0.5 < D < 0.8	0.3 < D < 0.6	IV	The development of digital village is lagging behind the level of high-quality agricultural development, with the system degraded	Grinding Stage
		V	Digital village and the level of high-quality agricultural development facilitate each other, with synchronized development and optimized system	
		VI	The development of the level of high-quality agricultural development is lagging behind the digital village, with the system degraded	
0.8 ≤ D ≤ 1	0.6 ≤ D ≤ 1	VII	The development of digital village is lagging behind the level of high-quality agricultural development, with the system degraded	Coordinated Stage
		VIII	Digital village and the level of high-quality agricultural development facilitate each other, with synchronized development and optimized system	
		IX	The development of the level of high-quality agricultural development is lagging behind the digital village, with the system degraded	

3.4. Geographical Detector

The geographical detector is a statistical method that detects the spatial differentiation characteristics within a region, which can reveal the evolution of the driving factors in an effective manner. In this paper, a spatiotemporal quantitative analysis of the influencing factors and their interactions on the coupling coordination between the digital village and the level of green and high-quality agricultural development in China was carried out by means of the factor detection and interaction detection methods with geographical detector.

The factor detection method is commonly applied to analyze the explanatory strength of each influencing factor on the spatiotemporal differentiation of the dependent variable using the following formula:

$$q = 1 - \frac{\sum\limits_{h=1}^{L} \mathrm{N_h}\sigma_h^2}{N\sigma^2}$$

Therein, q denotes the explanatory degree of the spatiotemporal differentiation of the dependent variable by this driving factor, h denotes the stratification of the variable, σ_h^2 and σ^2 denote the variance between the stratum sample and the full stratum, while N_h and N denote the number of units in stratum h and the full stratum.

The interaction detection method is available for the analysis of assessing whether the explanatory power of the dependent variable is strengthened or weakened when the influencing factors act together, with the specific measures presented in [56].

3.5. Data Sources

This study is based on the panel data for the period 2010–2019 of 31 provinces in China. Data on crop sown area, agricultural fertilizer use, total agricultural machinery power, effective irrigation area, and total output value of agriculture, forestry, animal husbandry, and fishery were obtained from *China Rural Statistical Yearbook* and *China Agricultural Statistical Yearbook*. Data on the number of postal online stores, penetration rate of telephones, length of optical fiber cable, number of 3G mobile phones, number of Internet broadband access ports, total post and telecommunications businesses, and freight volume were obtained from *China Statistical Yearbook* and *China Statistical Yearbook on Science and Technology*. Agricultural labor input data were obtained from the *China Labor Statistical Yearbook*, while the number of Taobao villages was obtained from the *China Taobao Village Research Report (2009–2019)*. The exceedingly minor missing data were supplemented by adopting linear interpolation. Meanwhile, for the sake of data comparability, the total output value of agriculture, forestry, animal husbandry, and fishery and the total transaction value of technology contracts were calculated according to GDP deflator of each province to obtain the actual level with the base period of 2000.

4. Results Analysis

4.1. Evaluation of Digital Village and Green and High-Quality Agricultural Development

As can be seen from Figures 2–4, the digital village indicator in China shows a rapid overall upward trend between 2010 and 2019, with an average annual growth rate of 4.27%, reaching a peak of 0.105 in 2019. From the perspective of the regional level, the eastern region exhibited the highest digital village indicator, while the central region exhibited the lowest. During the study period, the gap between the eastern and central digital village indicators expanded from 1.028 times to 6.795 times, which demonstrates that the development level gap of the digital villages between the regions in China has been progressively widening. From Figure 3, it can be revealed that the digital village indicator in the central region decreased remarkably in 2015 as the telephone penetration rate in Henan Province and Hubei Province decreased by 3.7% and 2.51%, respectively, in 2015, while the number of 3G mobile phone users in the two regions decreased by 14.28 million and 7.68 million, respectively, which resulted in a significant decrease in the digital village indicator in the two provinces, thereby causing a significant decrease in the digital village indicator in the central region. The significant decline in the digital village indicator in the western region in 2017 is likely attributed to the apparent decline in the number of mobile phone users in Guangxi, Chongqing, Guizhou, and Shaanxi, as well as the decline of 179 postal business outlets in Xinjiang. As a result, it can be concluded that the central and western regions should be alerted to the possibility of lagging behind and regression in digital infrastructure development, as well as negative fluctuations in Internet penetration as a result of socioeconomic development. In a general sense, the development of digital villages in China was basically coordinated and synchronized with regional economic development. Guangdong, Jiangsu, Zhejiang, Shandong, Fujian, Hebei, and other regions developed digital villages at a relatively fast pace. Judging from the front end of the industry chain, these regions are in the leading position in digital infrastructure construction and digital agriculture application on account of their favorable economic and agricultural foundations, where digital technology empowers agricultural production factors and propels materialized and nonmaterialized agricultural technologies to realize the digital transformation of agriculture and remarkably improve agricultural production efficiency. Judging from the back end of the industry chain, Zhejiang, Jiangsu, and Hebei stand out as the first regions where the rural e-commerce industry clusters emerged while also being at the forefront of the speedy development of in-depth applications in digital villages (source of information: China Taobao Village Research Report (2009–2019): Ten Years of Taobao Villages: The Road to Digital Economy for Rural Revitalization, The Ali Institute, 31 August 2019). The rural e-commerce industry clusters presented a highly uneven development status until 2019, when Zhejiang, Guangdong, Jiangsu, Shandong, Hebei, and Fujian turned out to be the provinces with a greater number of "Taobao villages" within China, whose cumulative total number of Taobao villages formed accounted for 95.43% of China.

The green total factor productivity of Chinese agriculture exhibited an upward trend with an average annual growth rate of 0.87% during the study period, which suggested that the level of green and high-quality agricultural development in China was rising. From the perspective of the regional level, the green total factor productivity of agriculture was the highest in the western region and the lowest in the central region, while the gap between the green high-quality agricultural development level in western and central China expanded from 1.053 times to 1.093 times from 2010 to 2019. Nevertheless, the green high-quality agricultural development level in China fluctuated considerably between regions in parallel. From Figure 4, it can be realized that the GTFP in the central region experienced apparent downward fluctuations in 2016, which was probably attributable to the fact that the total agricultural output value in Shanxi, Jilin, Henan, and Hunan provinces all experienced significant decreases in 2016. Moreover, the crop sowing area in

Anhui decreased by 160,000 hectares in 2016, while the total agricultural machinery power in Henan and Hubei decreased by 18.55 million kWh and 2.81 million kWh, respectively. In 2016, the GTFP in the western region demonstrated apparent upward fluctuations, which was probably attributable to the fact that the total agricultural output value in Guangxi, Chongqing, Sichuan, Guizhou, and Tibet all experienced apparent increases, while the agricultural carbon emissions in Sichuan and Chongqing decreased by 50,000 tons and 90,000 tons, respectively. As a result, it can be concluded that the government should rigorously guarantee crop sowing areas and increase agricultural machinery inputs to ensure the stable growth of agricultural output while encouraging the green and low-carbon transformation of agriculture, thereby advancing the sustainable development of green total factor productivity in agriculture. In a general view, the green total factor productivity indicators of agriculture were higher in Xinjiang, Shaanxi, and Qinghai at the initial stage of the study, as these regions experienced more traditional agricultural production methods and lower application of chemical inputs, such as fertilizers, pesticides, and agricultural films, resulting in a higher level of green and high-quality agricultural development. Following the development of the economy and agricultural technology, Jiangsu, Sichuan, Qinghai, and other regions have driven the transformation of their agriculture to green and high-quality agricultural development by reinforcing the promotion of green agricultural technology, sounding the green agricultural production system, as well as applying chemical inputs in a scientific and reasonable manner.

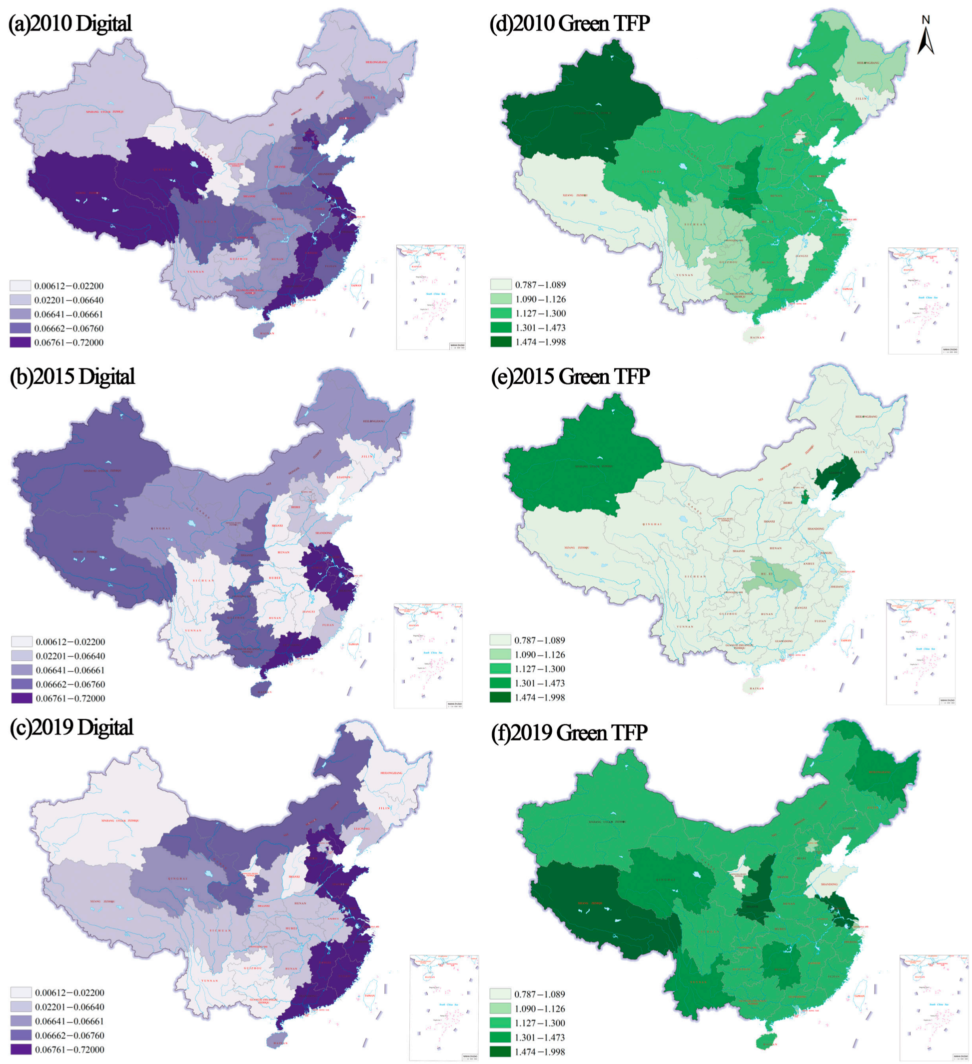

Figure 2. Spatiotemporal Evolution of Digital Village and Green and High-Quality Agricultural Development in China from 2010 to 2019.

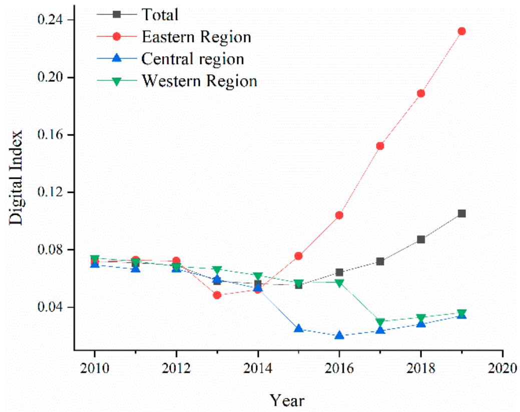

Figure 3. Evolutionary Trend of Digital Village Development in China from 2010 to 2019.

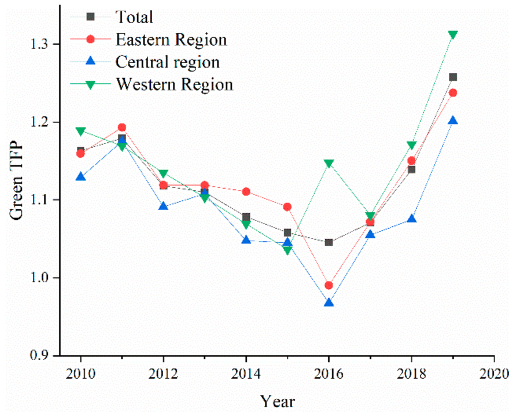

Figure 4. Evolutionary Trend of Green and High-Quality Agricultural Development in China from 2010 to 2019.

4.2. Analysis of Coupling Coordination Development of Digital Village and Green and High-Quality Agricultural Development

4.2.1. Spatiotemporal Differentiation Characteristics of the Coupling Degree of Digital Village and Green and High-Quality Agricultural Development

Digitization has emerged as a crucial power source for advancing sustainable agricultural development and rural modernization. The coupling coordination characteristics of digital village and green and high-quality agricultural development are capable of revealing the coordination evolution characteristics between new digital information elements and agricultural development in the context of the digital era, which is of great significance to further optimize the development of agricultural and rural modernization. For this reason, this paper employs a coupling coordination model to measure the coupling degree and coupling coordination degree between digital village and green and high-quality agricultural development in China, with the results shown in Figures 5–7.

From the national level, the coupling degree of digital village and green and high-quality agricultural development in China exhibited a trend of first decreasing and then fluctuating upward, with an average value of 0.428 during the study period and an average annual decrease of 1.09%. From the regional level, after decreasing from 0.369 in 2013, the coupling degree of the eastern region rapidly increased with an average annual growth rate of 9.43% to 0.677 in 2019, which represented the highest coupling degree in China. The coupling degree of the central region and the western region declined until 2016 and 2017, respectively, followed by slow growth to 0.311 and 0.306, respectively, in 2019. The further measurement revealed that the difference between the eastern region and the western region expanded from 0.997 times in 2010 to 2.067 times in 2019, and the difference between the central region and the eastern region expanded from 0.999 times to 2.034 times, while the difference between the central region and the western region expanded from 0.966 times to

1.021 times. It is noteworthy that the coupling degree of the western region was marginally higher than that of the central region in 2017 and 2018. From the perspective of coupling fluctuations, in the central regions of Hubei, Henan, Jiangxi, and Anhui during the period from 2014 to 2015, there was a significant decrease in the coupling degree of the two as a result of the remarkable decline in the level of digital villages; the western regions of Xinjiang, Ningxia, Shaanxi, Guizhou, Chongqing, and Guangxi experienced a significant decrease in the digital village indicator during the period from 2016 to 2017, while the GTFP indicator of Guizhou also experienced a noticeable decrease, therefore causing a substantial decrease in the coupling degree of the western region in 2017. The above analysis demonstrates that the gap between the coupling degree of digital villages and green and high-quality agricultural development in the eastern region, the central region, and the western region has gradually expanded, while the central region and the western region exhibited a comparable development trend. The coupling degree of the digital village and the green and high-quality agricultural development in China stabilized at around 0.45, which was in a low coupling state, suggesting that there might exist an unbalanced development between the two. In terms of the regional level, the provinces in the eastern part of China, such as Zhejiang and Jiangsu, have significantly improved both regional digital village and green and high-quality agricultural development through the digital transformation of infrastructure, the construction of digital infrastructure, the introduction of talents, the promotion of rural e-commerce clusters, and the transformation of green agricultural production. In this way, the coupling degree has increased substantially, which has enabled the two to promote each other and develop in a synergistic manner, as well as enter a coordinated development stage ahead of the central region and the western region.

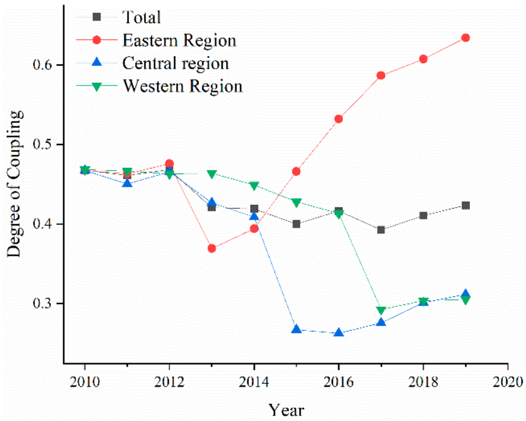

Figure 5. Evolutionary Trend of Coupling Degree of Green and High-Quality Agricultural Development in China from 2010 to 2019.

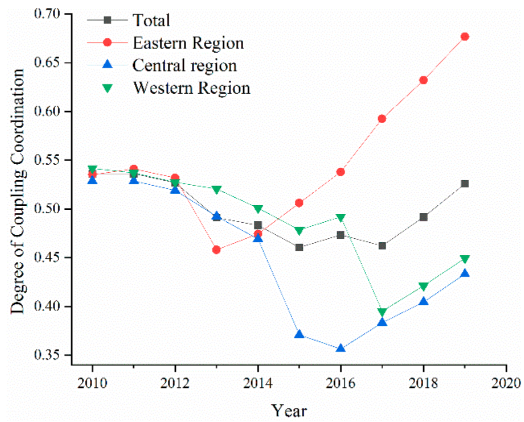

Figure 6. Evolutionary Trend of Coupling Coordination Degree of Green and High-Quality Agricultural Development in China from 2010 to 2019.

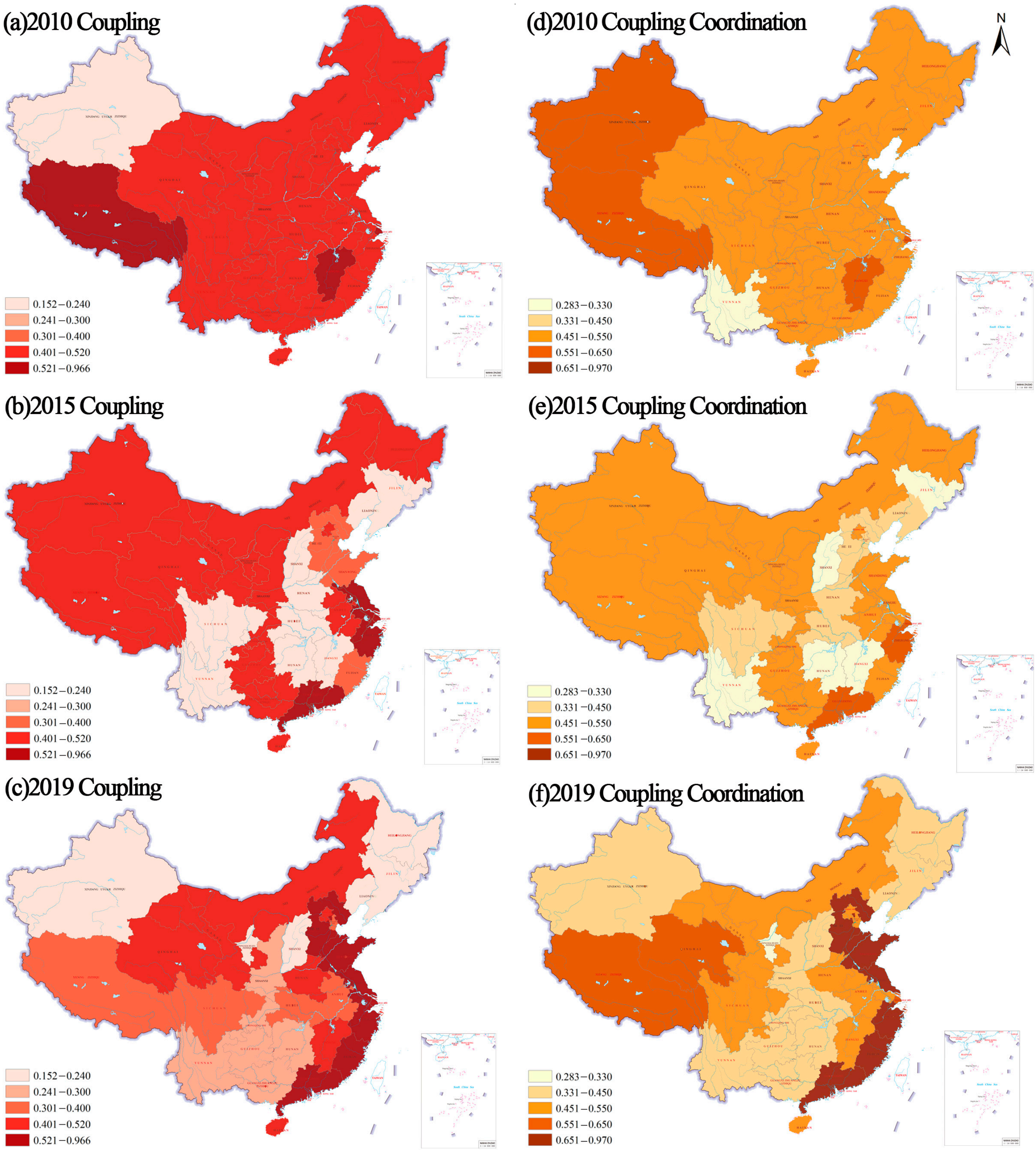

Figure 7. Spatiotemporal Evolution of Coupling and Coupling Degree between Digital Village and Green and High-Quality Agricultural Development in China from 2010 to 2019.

4.2.2. Spatiotemporal Differentiation Characteristics of Coupling Coordination Degree

As can be seen from Figures 5 and 6, judging from the national level, the coupling coordination degree of digital village and green and high-quality agricultural development in China presented the characteristics of first decreasing and then increasing, with the overall coupling coordination degree fluctuating around 0.55, which was in the grinding development stage with benign coupling characteristics. Nevertheless, there were significant differences in the coupling coordination degree in different years. In 2010, 96.78% of the provinces were in the grinding stage, while only Tibet was in the coordination stage; by 2015, nearly half of the provinces experienced system degradation, with the coupling coordination degree of the central and western provinces, such as Ningxia, Xinjiang, Jilin, Heilongjiang, Shanxi, and Yunnan, decreasing faster, while those in the grinding stage dropped to 87.09%, with Shanghai and Zhejiang developed to the coordination stage, whereas Yunnan and Jilin degraded to the antagonistic stage; by 2019, provinces in the grinding stage further dropped to 74.19%. It is notable that the coupling coordination degree of digital village and green and high-quality agricultural development in Zhejiang, Jiangsu, and Guangdong reached 0.969, 0.891, and 0.876, respectively, in 2019, which fulfilled benign resonance coupling and developed to a higher level of the coupling coordination stage. In terms of the regional level, the coupling coordination degree of the eastern region presented a rapid growth trend with a leading position after reaching the bottom in 2013, while the coupling degree of the central region and the western region exhibited a rebound trend after reaching the bottom in 2016 and 2017, respectively. During the study period, the difference between the east region and the central region expanded from 1.012 times to 1.562 times, and the difference between the east region and the west region expanded from 0.988 times to 1.506 times, while there was no significant difference between the central region and the west region, suggesting that the difference in the coupling coordination degree between digital village and green and high-quality agricultural development in the east region and the central and west regions of China has been progressively expanding. From the perspective of the fluctuation of the coupling coordination degree, there was a substantial decrease in the coupling coordination degree in the central and western regions during the period from 2015 to 2017. Since the digital village indicator and GTFP indicator in the central and western regions, such as Hubei, Henan, Jiangxi, and Guizhou provinces, experienced a significant decline, this, in turn, resulted in the overall coordinated development degree of the two systems of digital village and green and high-quality agricultural development exhibiting a decreasing trend. As a result, the government should make up for the shortfall in the coordinated development of digital villages and green and high-quality agriculture in relevant regions, with emphasis on preventing systemic degradation risks and facilitating the synergistic, stable, and healthy development of the two systems. The eastern provinces of China, such as Zhejiang, Jiangsu, and Shanghai, have always remained at the leading level in China in the process of digital village and high-quality agricultural development given their solid foundation of economy, talents, technology, and Internet platform carriers that contribute to the development of digital villages, with first-mover advantages and industrial cluster benefits. As a consequence, their digital village level has developed speedily, while agriculture has also taken the lead in high-quality development reform. In contrast, the central and western provinces, such as Tibet, Inner Mongolia, and Gansu, initially took the lead in green and high-quality agricultural development nationwide as a result of a comparatively favorable environmental base. Nevertheless, their Internet infrastructure construction and application have lagged behind, and their level of innovation development and technical conditions are backward, which has brought them to a slower level of digital village development, with a progressive increase in the gap with eastern provinces, thereby making their digital villages incompatible with green and high-quality agricultural development.

4.3. Analysis of the Driving Mechanism of Spatiotemporal Differentiation of Coupling Coordination between Digital Village and High-Quality Agricultural Development

On the basis of the above study, it is revealed that the spatiotemporal evolution of coupling coordination between digital village and high-quality agricultural development in China exhibits an apparent spatial differentiation, while its inner drivers have not been clarified. For the sake of probing the driving factors affecting the spatiotemporal differences of coupling coordination between digital village and high-quality agricultural development in China, a geographical detector model was specially applied to detect the coupling coordination degree and explore the evolutionary trends of the inner driving forces. On the basis of the coupling logic of digital village and high-quality agricultural development [19,25,57], this study selected 10 influencing factors, as shown in Table 4, from three dimensions of economic, social, and agricultural industry development, in addition to utilizing the factor detection method with a geographical detector to examine the magnitude of the driving force of each factor on the coupling coordination degree of digital village and high-quality agricultural development in China at various periods. Taking into account that rural e-commerce was still in its preliminary development stage from 2009 to 2012, and most provinces achieved a turnaround of coupling coordination from decline to growth in 2015, three periods of 2013, 2016, and 2019 were selected for analysis in this paper. With regard to the factor indicators, the economic dimension covers the economic level (GDP per capita, x1), rural per capita income (net income per rural household, x2), industrial structure (value added by secondary industry as a proportion of GDP, x3), as well as agricultural financial input (agricultural, forestry, and water financial input, x4). On the other hand, the social dimension covers the level of innovation (number of patents granted, x5), the level of education (financial expenditure on education, x6), and environmental regulation (investment in environmental pollution control as a share of GDP, x7). The agricultural development dimension covers agricultural scale (arable land area, x8), agricultural technology (total power of agricultural machinery, x9), and e-commerce (number of Taobao villages, x10).

The factor detection structure is shown in Table 4, in which the explanatory strength of each factor on the spatial analysis of the coupling coordination degree of digital village and high-quality agricultural development in China develops a remarkable variation over time. In 2013, four influencing factors exerted significant effects, with their explanatory strength ranked as follows: e-commerce > education level > agricultural technology > industrial structure, in which e-commerce and innovation level were the major core factors. By 2015, the ranking of the influence factors varied, with the specific manifestation of e-commerce > economic level > innovation level > education level; by 2019, the ranking further varied to e-commerce > innovation level > per capita income > education level, with e-commerce always being the core influence factor. The factor detection results demonstrate that e-commerce (0.59), per capita income (0.36), economic level (0.33), and innovation level (0.33) are the primary factors affecting the degree of coupling coordination between digital village and the green and high-quality agricultural development in the overall context. From the perspective of the time dimension, among them, in line with the coupling coordination development of the two, the q-values of agricultural financial input, agricultural technology, and industrial structure decreased by 16.26%, 14.38%, and 5.44% annually, suggesting that the degree of their influence had progressively decreased, while the q-values of innovation level and economic level increased by 9.55% and 4.46% annually, suggesting that the degree of their influence had progressively increased. These were primarily attributed to the fact that the digital village has gradually entered the application stage with the development of rural e-commerce, which has, in turn, propelled green and high-quality agricultural development and rapid regional economic development, further injecting development momentum into the construction of the digital village. Through the aggregation effect of rural e-commerce industry, agriculture has been driven to achieve innovation in the products, services, and branding of the whole industry chain to motivate agricultural practitioners to improve their human capital while enhancing the production efficiency of farmers and regional economic development to support the construction of the digital village. In this context, the construction of digital village and high-quality agricultural development can achieve positive interaction and synergistic development, which is instrumental in advancing and realizing the objective of agricultural and rural modernization in the new era.

Table 4. Detection Results of Influencing Factors for the Coupling Coordination Degree of Digital Village and High-Quality Agricultural Development.

		All Periods			2013		2016		2019	
		q	*p*	Influence Ranking	q	Influence Ranking	q	Influence Ranking	q	Influence Ranking
Economic Indicators	Economic Level (x1)	0.33	0.00	4	0.34	5	0.45	2	0.46	5
	Per Capita Income (x2)	0.36	0.00	2	0.34	6	0.24	7	0.52	3
	Industrial Structure (x3)	0.20	0.12	6	0.37	4	0.25	6	0.25	6
	Agricultural Financial Input (x4)	0.06	0.77	8	0.30	8	0.20	8	0.09	10
Social Indicators	Innovation Level (x5)	0.33	0.00	3	0.32	7	0.41	3	0.61	2
	Education Level (x6)	0.25	0.01	5	0.51	2	0.35	4	0.51	4
	Environmental Regulation (x7)	0.06	0.72	9	0.09	10	0.11	10	0.10	9
Agriculture Industrial Development	Agricultural Scale (x8)	0.11	0.27	7	0.14	9	0.27	5	0.14	7
	Agricultural Technology (x9)	0.05	0.71	10	0.40	3	0.15	9	0.13	8
	E-commerce (x10)	0.59	0.00	1	0.85	1	0.61	1	0.78	1

Meanwhile, taking 2019 as an instance, the results of the interaction detection of the above various influencing factors are shown in Figure 8. The explanatory power of the coupling coordination degree between digital village and high-quality agricultural development is primarily manifested as nonlinear enhancement and two-factor enhancement among the influencing factors, with nonlinear enhancement accounting for more. The explanatory power of per capita income (x2), education level (x6), agricultural scale (x8), and e-commerce (x10) after interacting with other influencing factors was remarkably greater than the sum of two-factor accumulation, which exhibited a nonlinear enhancement. This demonstrates that the further promotion of e-commerce development, the improvement of education levels, the promotion of agricultural scale and intensive production, and the increase of per capita income in conjunction with other factors will exert a strong overlapping promotional effect on the improvement of the coupling coordination degree between digital village and high-quality agricultural development. As a consequence, the construction of targeted multicombination development strategies on the basis of regional socioeconomic and agricultural industry development will be instrumental in advancing the mutual promotion and synchronization of the development of digital villages and green high-quality agriculture in the region to upgrade the modernization level of agricultural and rural development in the new era.

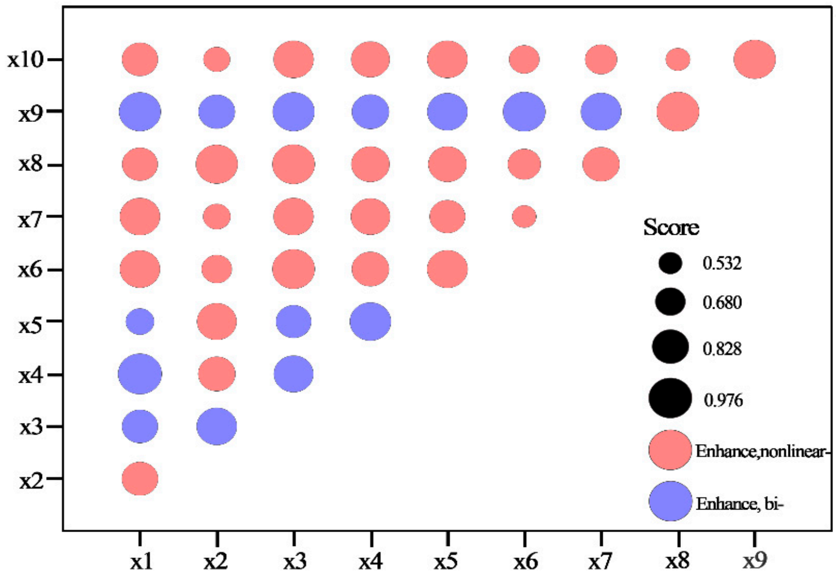

Figure 8. Interaction Detection Results of Coupling Coordination Degree between Digital Village and Green High-Quality Agricultural Development in China.

5. Conclusions and Policy Implications

By constructing a comprehensive evaluation indicator system for digital villages in China, this paper evaluated the development status of digital villages in China by means of the entropy weight–TOPSIS method, while calculating the green total factor productivity (GTFP) of agriculture in China by means of the GML indicator on the basis of the SBM model. In this way, a coupling coordination degree model and a geographical detector were employed to examine the coupling coordination characteristics and the driving factors of digital village and green high-quality agricultural development in China. It was found that:

(1) From 2010 to 2019, the development level of digital villages in China exhibited a rapid upward trend, with an overall spatial distribution pattern of high in the east region and low in the west and central regions, while the gap between the development level of digital villages in the east region and the central and western regions has been progressively expanding. Green and high-quality agricultural development in China presented a steady increase; from the regional level, the western region was high, and the central region was low, while the difference in the level of green and high-quality agricultural development in China has been narrowing progressively. Since 2015, the lagging digital infrastructure and regression of the digital popularization rate in the central and western regions, such as Henan, Hubei, Guangxi, and Xinjiang provinces, have brought about a significant decrease in the level of digitalization in the central and western regions. In 2016, Anhui, Henan, and Hubei provinces brought about a significant decrease in the GTFP indicator in the central region as a result of a substantial decrease in total agricultural output value and total agricultural mechanization power;

(2) The coupling degree and coupling coordination degree of digital village and green and high-quality agricultural development in China exhibited a first decreasing and then increasing trend, with significant spatiotemporal difference patterns. During the study period, the coupling coordination degree of various provinces in China was in the grinding stage and progressively evolved to the coordination stage. In terms of the spatial dimension, the provinces with a high coupling coordination degree were primarily concentrated in the area east of the Hu Huanyong line (also known as Hu Line). In terms of the spatial pattern evolution, digital villages and green and high-quality agriculture in the eastern region have progressively tended to develop in a synergistic manner, while the lagging development of digital villages in the central and western regions has turned out to be a deficiency limiting the synergistic development of both. During the period 2015 to 2017, the overall system was at risk of degradation as a result of the decline in the digital village indicator in the central and western regions, which led to a noticeable decrease in the level of coupling coordination between the two;

(3) The coupling coordination development of digital village and green and high-quality agricultural development in China is the result of the combined effect of several factors. Rural e-commerce stands out as the most significant factor contributing to the coupling development of both, while the economic level, innovation level, and per capita income exert a crucial driving role in the coordinated development of both. From the perspective of the time dimension, the degree of influence of agricultural financial input, agricultural technology, and industrial structure on the coordinated development of the two has progressively decreased, while the degree of influence of innovation levels and economic levels has progressively increased.

In light of the above conclusions, with a view to further advancing the synergistic development of digital village and sustainable agricultural development, this paper puts forward the following suggestions:

First and foremost, it is necessary to keep pushing forward the construction of digital villages and reinforce the digital empowerment of green and high-quality agricultural development. Meanwhile, it is recommended to keep advancing the construction of digital villages and regional resource endowment with adaptations to local conditions, to match the industrial base and agricultural industry structure, and to make full use of digital farming technology with the help of Internet platforms, in addition to constantly perfecting the modern agricultural industry chain. On the basis of the improvement of digital infrastructure, the government is expected to organize and conduct digital skills training targeting farmers and agricultural production enterprises. In addition to further increasing financial investment in digital villages, relevant agricultural production service enterprises and social capital should also be encouraged to engage to build a diversified digital village participation mechanism led by the government and involving society. The county-level governments should be encouraged to build a digital agricultural big data platform and achieve agricultural data sharing and assisted decision-making by building a unified agricultural data aggregation and analysis decision-making system relying on technologies, such as the Internet of Things, block chain, and big data. In addition, attention should be paid to the impact of digitalization on green agricultural development to encourage the main body of agricultural production, with digitalization and intelligent development, to release a driving effect on green and high-quality agricultural development, to facilitate the main body of agricultural production to take the road of digitalization and green integration, and to cultivate new dynamics of digital and green agricultural development to jointly fulfill green and high-quality agricultural development in China. For instance, the digital agricultural model can assist agricultural production subjects to recognize the inner rules of agricultural production and the external environment, such as crop production rules and the relationship between fertilization and irrigation and crop yield, which is instrumental for production subjects to save agricultural production factors and reduce agricultural surface source pollution, thereby achieving the objective of sustainable agricultural development.

The second is to implement a digital strategy with regional differences. In accordance with the research of this paper, it can be revealed that digital village and green and high-quality agricultural development in the eastern region tends to develop in a synergistic manner, while the synergistic development in the western region is slower, and the digital village in the western region is less developed. In this way, emphasis should be placed on strengthening the digital infrastructure, firmly establishing the foundation of digital technology application, advancing the cultivation of digital agricultural industry, and upgrading the digital level of agriculture, thereby unleashing the dividends of digital economy-driven green and high-quality agricultural development.

The third is to facilitate the development of rural e-commerce to drive the development of digital villages and green and high-quality agriculture. It is essential to make full use of e-commerce development to upgrade the level of digital villages and improve agricultural production efficiency, to proactively plan and layout the development strategy of rural e-commerce, and to boost the construction of digital platforms. In addition, importance should be given to the integration of digital platforms to create a new agricultural industry chain, to make up for the disconnect issues between traditional agricultural production and sales, to give full play to the advantages of local special industries, to take full advantage of e-commerce channels, and to propel the agricultural management system and production methods to make progress towards green modernization, thereby laying solid foundations for sustainable agricultural development.

The fourth is to reshape the public service function of the government and achieve the modernization of rural governance. In the process of advancing the construction of digital villages and green and high-quality agricultural development, the government is expected to reshape its public service function by building digital infrastructure, fostering the digital agricultural industry, and boosting e-commerce development and other measures to clarify the identity of the government as a public service provider, while integrating with digital village governance and dedicating to the modernization of rural governance.

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