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Spatial Distribution Characteristics and Influencing Factors of Agricultural Specialized Villages in Guangdong Province, China

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Abstract: China is vigorously implementing a rural revitalization strategy with the prosperity of rural industries as the primary goal. The characteristic economy of 'One Village One Product' (OVOP) is particularly significant in promoting rural revitalization and increasing farmers' income. Accurately identifying the spatial distribution characteristics and influencing factors of agricultural specialized villages (ASVs) under OVOP provides a preliminary research basis for constructing the theoretical framework of specialization and clustering of rural industrial development. This study takes Guangdong Province, China as an example, using kernel density estimation, Ripley's *K* function, geometric fractals, principal component regression and other methods to identify the spatial distribution characteristics and influencing factors of ASVs. It was found that the ASVs in Guangdong Province are dominated by the planting industry, with an uneven number in space and a multi patch distribution. Specifically, ASVs are mainly distributed in the Chaoshan Plain in the eastern Guangdong, the northern mountainous area of Guangzhou, and the eastern part of Maoming City. Its spatial distribution mode obeys the aggregation distribution pattern at the scale of province, region and municipality (prefecture-level city). In addition, the formation and development of ASVs are affected by multiple internal and external factors. The influence of basic factors such as natural environmental conditions is gradually weakening, while the influence of social and economic factors such as market demand is gradually increasing. This study can enrich the research results of ASVs and provide guidance and reference for the long-term and high-quality development of rural industry revitalization.

Keywords: One Village One Product (OVOP); agricultural specialization; spatial distribution; rural industry revitalization

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1 Introduction

Rapid industrialization and urbanization have weakened rural economic, social and cultural development, rural recession and other common problems occur frequently (Liu and Li, 2017; Li et al., 2019; Zhu et al., 2019). In China, this transformation of rural areas brings significant challenges (Wang et al., 2016; Zang et al., 2020). For this reason, the Chinese government proposed implementing rural revitalization and promoting the integrated development of urban and rural areas (Han, 2019). The development of agriculture, rural areas, and peasants is considered a core issue to be addressed in rural development transformation in China. It involves the re-

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construction of multiple rural spaces and the orderly evolution and optimal regulation of the rural regional system has become both the focus and the challenge for researchers of rural geography in China (Long and Liu, 2016).

In 2017, China's government proposed the implementation of rural revitalization strategy in the report of the 19th National Congress of the Communist Party of China. This strategy aimed to effectively solve the problems of rural development, comprehensively promote the development and transformation of rural areas in China, and realize the integrated development of urban and rural areas. With rural development and transformation, and the reconstruction of multidimensional space, where specialization characteristics and the scale of agricultural production are becoming increasingly prominent (Long, 2013). The development and prosperity of the village economy, in association with industrial prosperity, have become primary topics in implementing the rural revitalization strategy (Liu, 2018). In 2019, the State Council of China issued an official document to encourage farmer cooperatives and family farms to develop primary processing of agricultural products (http://www.gov.cn/zhengce/content/2019-06/28/content_5404170.htm).

Moreover, the government prodded and built several specialized villages according to specialized division of labor and production or engaged in a certain industry, responding to the concept of 'One Village One Product' (OVOP). Among them, the specialized villages focusing on agricultural production and sales of agricultural products are called agricultural specialized villages (ASVs). The development of ASVs is vital in promoting agricultural efficiency and increasing farmers' income. The development mode with ASVs as the basic unit in association with the agglomeration of small-scale farmer production in the region is an essential characteristic of the agricultural development pattern in China (Yang et al., 2020).

China has recently vigorously implemented rural revitalization strategy and steadily promoted agricultural modernization. Agriculture and rural areas still hold an irreplaceable position in ensuring the development of an industrialized economy. ASVs were used in the golden period of growth. Guangdong Province is located in the economically developed southeastern coastal area of China. As one of the regions with the best agricultural development in China, it has a long agricultural history and superior resource endowment. The development of ASVs in this region has attracted increasing attention from many stakeholders, the promotion of OVOP has also achieved good practical results initially. Because of this, based on the identification results of the first and second batches of OVOP in Guangdong Province, this study comprehensively integrates the appropriate methods of quantitative geography and spatial analysis techniques to explore the spatial characteristics of ASVs in Guangdong Province. Then it identifies the influencing factors on their spatial distribution to provide a reference for the sustainable development of ASVs for China and other countries and regions in the world.

2 Literature Review

The concept of OVOP originated in Japan and played an essential role in their rural construction and rehabilitation movement (Mukai and Fujikura, 2015). The concept has matured and become the global mode for the development of rural areas. Governments usually initiate the planning and are mostly organized 'top-down' (Hariani, 2019). It is a participatory rural development mode focusing on local characteristics, improving rural welfare, and realizing equality by empowering collective organizations or farmers. This strategy of local people using locally available resources to produce unique regional products enables more people to participate, adding value to these products that are passed down from generation to generation. OVOP can also contribute to the development of tourism, effectively improve the well-being of local people, and further promote regional economic development (Cahyani, 2013; Issa and Laval, 2014; Yuan and Lu, 2017; Hakim, 2018; Irawan, 2019; Koswara et al., 2019; Rakhmawati, 2019; Indriani, 2020).

The effectiveness of industrial development, project implementation, economic and social impacts, and other issues are the major research points on ASVs in the world. Relevant studies mainly adopt methods of qualitative analysis and case studies, including interviews (Eisazadeh, 2021), SWOT analysis (Hadi et al., 2017), non-probabilistic sampling (Manalu and Akbar, 2020), proportional random sampling (Kusumawardhani et al., 2016), design thinking methods (Ndione and Suzuki, 2019), *etc*. Many empirical studies show that the OVOP mode applies to both developed and developing countries. It is a way to promote regional sustainable development and effectively deal with other challenges such as poverty reduction, revitalizing poor rural communities, narrowing the income gap, and expanding employment opportunities (Schumann, 2016; Kumarananda et al., 2018). In recent years, the upsurge of implementing OVOP in the rural areas of western developed countries has gradually faded, where it has begun to turn to the development of rural tourism, the rural elderly care industry, and rural industrialization (Woods and McDonagh, 2011; Berdegué et al., 2015). In contrast, this mode has become an important way for some developing and less developed countries to achieve rural development.

In addition, the recent experience of some countries in implementing OVOP is worth learning. In some areas, local governments have increased publicity among farmers so that farmers can better understand OVOP, and thus improve farmers' enthusiasm for the programme (Kusumawardhani et al., 2016). Moreover, local governments have also greatly enhance employees' participation through various measures to increase their opportunities for contributing to the programme (Indana and Sukidjo, 2020). For example, villages in Bali have established women's learning groups to develop OVOP further to improve their participation and independent business skills using internal resources to increase income (Sanjaya et al., 2017). Thailand has also organized English training courses for employees of OVOP programmes to better promote local products across the globe (Nithitwaraphakun, 2020).

However, comprehensive research on the practice and theoretical construction of the OVOP and ASVs in Chinese academic circles is lagging. The research perspective mainly focuses on the following aspects. In terms of formation and development, including research progress and review (Qiao and Yang, 2013), establishment conditions and evolution mechanisms (Li et al., 2009), development history and influencing factors (Liu, 2020), *etc*. In terms of spatial distribution, including spatial patterns and agglomeration effects (Cao et al., 2020), temporal and spatial evolution and diffusion laws (Chu et al., 2020), *etc*. In terms of organization and operation, including development power and paths (Shi et al., 2014), business modes and organizational forms (Ye, 2014), *etc*. In terms of development status and future trend, including existing problems and dilemmas (Wu and Li, 2016), transformation and upgrading (Wang, 2019) and other aspects. Chinese scholars also pay attention to the impact of geographical environment factors and stakeholders on the formation and development of ASVs (Wu et al., 2014). The ensuing multiple effects have caused deeper thinking and debate. It is worth mentioning that research on the spatial distribution characteristics and driving mechanisms for the implementation and development of ASVs in typical areas of agricultural development in China is still insufficient at the village scale and needs further exploration.

In terms of the theoretical basis of research of ASVs, its theoretical basis is mostly from the field of economics, and it integrates the theories of geography, sociology and other disciplines, such as the spatial interface theory (Qiao and Li, 2014), industrial agglomeration and the scale economy theory (Yang, 2019), the regional spatial structure and the multi-level network theory (Qiao et al., 2016), the labor division and specialization and the rational peasant theory (Li et al., 2012b), actor network theory (Liu and Li, 2009), the law of distance decay and the neighborhood effect (Li et al., 2018). In terms of research methods, most of the previous studies were qualitative studies. In recent years, quantitative analysis has gradually increased, and a development trend of combining qualitative and quantitative analysis has emerged. On the one hand, the spatial distribution and agglomeration effect of ASVs are explored by using the nearest neighbor index (Shao et al., 2016), spatial autocorrelation and hotspot analysis (Ma et al., 2018) in GIS spatial analysis. On the other hand, the influencing factors of the formation and evolution of ASVs are detected and identified by means of Geodetector (Chen et al., 2019; Cao et al., 2020) and regression analysis (Zhou and Li, 2015; Hu and Hou, 2017), so as to reveal the process of the formation and development of ASVs and the driving mechanism attributable to their formation and evolution. For example, Zhu et al. (2022) took 50 specialized villages in Henan Province, China as an example, and combined qualitative and quantitative methods to explore the spatial and temporal changes of the sales market of specialized villages in Henan Province. Among them, standard deviational ellipse (SDE) is used to reveal the spatial distribution pattern, social network analysis (SNA) is used to describe the structural characteristics of the overall network, Geodetector is used to explore the driving force behind, and diffusion distance model (DDM) is used to measure the diffusion distance and diffusion speed. As a typical example of specialized agricultural production, ASVs have gradually formed regional specialized production patterns through the spillover effect (Wu and Li, 2017). While making significant contributions to the rural economy, the plan still faces social, economic, technological, and other obstacles. There are many practical problems, particularly in some underdeveloped areas, such as low brand awareness, weak awareness of farmer participation, small production scales, lack of infrastructure, insufficient technology investment, scarcity of innovative talent, low industrial integration, and limited financial support (Wang et al., 2018). In short, developing the distinctive economy of OVOP and actively constructing ASVs in China is an additional specific measure that promotes rural revitalization and increases farmers' income. It must be noted that opportunities and challenges will coexist during the process of future development.

3 Materials and Methods

3.1 Study area

Guangdong is located in a low latitude region of China (Fig. 1). It has a tropical monsoon climate with long summers and warm winters. The land area represented about 179 800 km^2, accounting for approximately 1.87% of the national land area. The island area represented 1600 km^2, accounting for about 0.89% of the entire province. The characteristic elevation is generally high in the north, being mostly mountainous with high hills. On the other side, the elevation in the south is flat, where plains and terraces dominate. The Pearl River and its tributaries run through the north and south, with vertical and horizontal river networks and fish ponds everywhere. The Pearl River Delta is the most extensive plain in the province, followed by the Chaoshan Plain in the east. Besides, Guangdong Province faces the South China Sea in the south, with vast sea areas, numerous islands, and rich marine resources.

In terms of administrative divisions, Guangdong Province governs 21 prefecture-level cities. According to the geographical location of each region in the province, it can be divided into four regions: the Pearl River Delta (PRD), the Eastern Region (ER), the Western Region (WR), and the Northern Region (NR). PRD includes nine prefecture-level cities: Guangzhou, Shenzhen, Foshan, Dongguan, Zhongshan, Zhuhai, Jiangmen, Zhaoqing, and Huizhou. ER generally refers to four prefecture-level cities: Shantou, Chaozhou, Jieyang, and Shanwei. WR includes three prefecture-level cities: Zhanjiang, Maoming, and Yangjiang. NR includes five prefecture-level cities: Shaoguan, Qingyuan, Yunfu, Meizhou, and Heyuan (Fig. 1). Regarding economic aggregate, Guangdong Province ranked first in China for 32 consecutive years. In 2020, the regional GDP of Guangdong was 11 076.094 billion yuan (RMB), accounting for approximately 10.9% of the national GDP, of which the proportion of primary, secondary, and tertiary industries was 4.30 ∶ 39.20 ∶ 56.50, respectively. At the same time, Guangdong is also the most populous province in China, with a permanent resident population of 126 million in 2020 and scarce cultivated land resources (Guangdong Bureau of Statistics, 2021).

Guangdong Province has a long history of engaging in agricultural production. The region was one of the earliest in the history of China to practice commercial agriculture with a capitalist mode of production. In recent years, the reform of urban-rural integrated development systems in the province has improved farmers' agricultural output value and net income. Rice is the main food crop; cash crops are mainly vegetables, fruits, and sugarcane, which have achieved a high degree of specialization, and the degree of agricultural agglomeration shows a fluctuating upward trend (Xiao, 2013; Huang and Zhong, 2017). Agricultural competitiveness is high nationwide, but there is still a significant gap in the level of agricultural development between regions

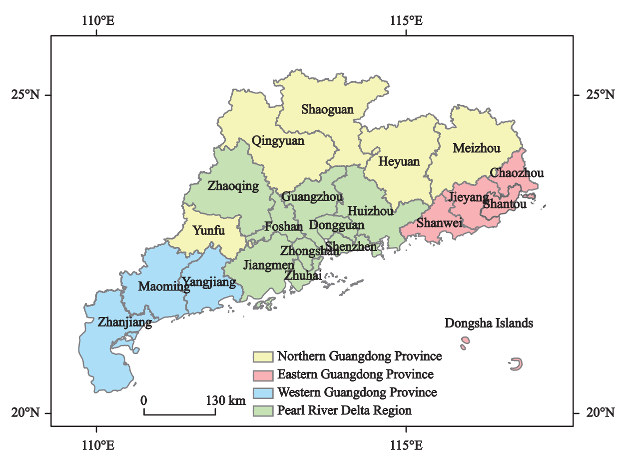

Fig. 1 Geographical location of Guangdong Province, China and its four major regions

and cities in the province (Wei et al., 2020). Since the 'One Village One Product, One Town One Industry' launch in 2019, 2277 provincial-level ASVs and 300 provincial-level specialized agricultural towns have been identified in Guangdong Province. Among them, 50 new villages and towns have been selected as national demonstration settlements. This situation is the most significant number in the country, which has effectively stimulated the vitality of new products and business entities at the grassroots level, creating a development environment conducive to the specialized production and large-scale operation of this region's agriculture.

3.2 Data and variables

The ASVs involved in this study come from the first and second batches of the ASV identification list of 'One Village One Product, One Town One Industry' issued by the Guangdong Provincial Department of Agriculture and Rural Areas, including 1323 from the first batch (https://mp.weixin.qq.com/s/HdkxqxsYX7T9WKxFSnmuGw) and 954 from the second batch (https://mp.weixin.qq.com/s/cqWVRctyklt6sh4m_irW8w), totaling 2277 villages. The longitude and latitude coordinates of each ASV were collected on the Baidu website (https://api.map.baidu.com/lbsapi/getpoint/index.html). The *Guangdong Statistical Yearbook* and *Guangdong Rural Statistical Yearbook* databases were also helpful for obtaining the population and economic statistics (Guangdong Bureau of Statistics, 2021). Or the Digital Elevation Model (DEM) and meteorological data were obtained from the Earth System Science Data Sharing Platform of the Institute of Geographic Sciences and Resources, Chinese Academy of Sciences (http://www.geodata.cn/). The road traffic accessibility data came from the 1: 250 000 electronic maps of China in 2012 (Yang, 2017), and agricultural land type data were obtained from the statistical summary data of land area by the Department of Natural Resources of Guangdong Province at the end of 2018 (http://nr.gd.gov.cn/). Taking the districts and counties of Guangdong Province as the research unit, the influencing factors and degree of the spatial distribution of ASVs can be identified quantitatively based on the relevant data from 124 districts and counties in the province. Because of the comprehensive influence of multiple factors from different dimensions on the formation and development of agriculture, this study divides the factors that may affect the spatial layout of ASVs into four dimensions: economy and population, natural environment, traffic accessibility, and agricultural resource endowment. Therefore, 15 indicators relevant to the research were chosen for comprehensive measurement. Table 1 provides these indicators.

First, the formation and development of ASVs depend on rural population, particularly farmers directly related to agricultural production. In addition, as a development mode for characteristic agriculture, the general development level of agriculture may impact the development of ASVs. Promoting urban-rural integration also encourages interaction between urban and rural areas. Moreover, the level of regional economic growth is also an influencing factor to be considered. Therefore, in terms of economy and population, four indicators were selected (x_1–x_4). Second, the long-term agricultural climate, landforms, water sources, and other natural background conditions in the region significantly impact the planting systems and development of ASVs. Thus, five indicators (x_5–x_9) have been selected for the natural environment. Simultaneously, modern agricultural production depends on traffic accessibility to ensure the efficient flow of resources between urban and rural areas. Therefore, the traffic accessibility dimension can be assessed through three indicators (x_{10}–x_{12}). Each resistance value can be calculated according to the minimum cumulative resistance value model (MCR), which was first proposed by Knaapen et al. in 1992 (Knaapen et al., 1992) and was revised by Yu Kongjian in 1999 (Yu, 1999). In addition, agricultural land provides the material basis and spatial carrier for ASVs to support agricultural production activities. Therefore, the dimension of agricultural resource endowment can be assessed using the following three indicators (x_{13}–x_{15}) (Table 1).

3.3 Methods

This study integrates various analytical methods to quantify the spatial distribution characteristics and influencing factors of ASVs in Guangdong Province. Specifically, each ASV can be abstracted as a point of interest (POI) in space. As a result, analyzing the spatial point mode of ASVs in the study area is possible. In a different strategy, Ripley's *K* function, geometric fractals, and kernel density estimation are helpful research techniques employed to describe the spatial dis-

Table 1 Index system influencing the spatial distribution of agricultural specialized villages (ASVs)

Dimension	Variable	Source
Economy and population	Rural population (x_1)	Guangdong Statistical Yearbook (2021) and Guangdong Rural Statistical Yearbook databases (2021)
	Labor force of primary industry (x_2)	
	Gross domestic product (GDP) (x_3)	
	Total output value of agriculture, forestry, animal husbandry, and fishery (x_4)	
Natural environment	Elevation (x_5)	The Earth System Science Data Sharing Platform of the Institute of Geographic Sciences and Resources, Chinese Academy of Sciences
	Slope (x_6)	
	Distance from main rivers (x_7)	
	Average temperature (x_8)	
	Annual Precipitation (x_9)	
Traffic accessibility	Accessibility resistance to prefecture-level cities (x_{10})	The 1: 250 000 electronic maps of China in 2012 (https://map.bmcx.com)/
	Accessibility resistance to counties and districts (x_{11})	
	Accessibility resistance to villages and towns (x_{12})	
Agricultural resource endowment	Area of cultivated land (x_{13})	The statistical summary data of land area by the Department of Natural Resources of Guangdong Province at the end of 2018
	Area of garden (x_{14})	
	Area of forest (x_{15})	

tribution, from which the distribution mode and aggregation features of ASVs can be identified. The specific operation of kernel density estimation, Ripley's K function and geometric fractal were carried out using ArcGIS 10.2. Moreover, this framework provides for the quantitative and logical identification of the influencing elements, and principal component regression was adopted to explore the influencing aspects of ASVs.

3.3.1 Kernel density estimation

On a specific scale in the region, the density and intensity of the distribution mode of the set of points of ASVs in terms of probability at any point are measurable, with kernel density estimation being the standard method. Kernel density estimation (KDE) was proposed by Rosenblatt and Parzen in 1955 and 1962, respectively (Rosenblatt, 1956; Parzen, 1962). This is a nonparametric method for estimating probability density function (PDF). Its principle is that geographical events can occur anywhere in space, but the probability of the occurrence of geographical entities or events in different spatial locations is different. The following equation was used in this study to show the distribution pattern of ASVs.

$$fn(x) = \frac{1}{nh}\sum_{i=1}^{n} k[(x - X_i)/h] \quad (1)$$

where X_i is the event, $k[(x–X_i)/h]$ is the kernel function, h is the bandwidth ($h > 0$), n is the number of ASVs in the study area, and $(x–X_i)$ is the distance from the valuation point to the event X_i.

3.3.2 Ripley's K function

Ripley proposed Ripley's K-function in 1976 (Dixon P M, 2006). It can analyze the clustering degree of point datasets at different distances. The defect of the G and F functions is that only the nearest space is used to measure the point mode, and only the mode of spatial points on a single scale is considered, whereas the K function considers all distances between point pairs. It is a function model that can reveal the second-order properties of the spatial point mode and scale dependence at multiple scales (Lu, 2019). According to the principle of the K function, when the distance changes, the centroid, and several contained elements will change, and the data density will also change. The K function can indicate the degree of spatial aggregation or spatial diffusion of these element centroids and how they will change when the neighborhood size changes. Because the entire data distribution is nonlinear, the discrete state or distance presented is more of a qualitative expression. To know the distance at which the aggregation effect of the set of points is good, and the degree of dispersion is large, one usually needs to compare ObservedK and ExpectedK in the results. ObservedK (generally equal to the actual density value) is the real density value calculated using the K function, and ExpectedK is usually equal to the distance. In the algorithm of the K function, ExpectedK is determined by setting a random number. The calculation formula is as follows:

$$\widehat{K}(d) = \lambda^{-1} E[n] \tag{2}$$

where λ is event density. From the results, the specific values of five variables can be obtained: ExpectedK, ObservedK, DiffK (difference between ExpectedK and ObservedK), LwConfEnv (low-value confidence interval), and HiConfEnv (high-value confidence interval). If ObservedK > ExpectedK, the clustering degree of the distribution is higher than that of the random distribution of the distance (analysis scale). If ObservedK < ExpectedK, the distribution is more discrete than the random distribution of the distance.

3.3.3 Geometric fractals

Fractal methods are often used to study the distribution patterns of the set of points of ASVs, including geometric fractals based on the European plane and structural fractals based on topological relationships. Fixed radius and box covering methods are often used in geometric fractals. The fixed radius method considers the spatial heterogeneity based on the distance attenuation law and then judges the distribution mode of the set of points. The box-covering process describes the morphological complexity of the set of points from the perspective of space-filling ability (Lu, 2019).

Because this study mainly explores the spatial distribution mode differences of the set of points of ASVs in Guangdong Province, it does not involve a complex network structure. The overall distribution characteristics of ASVs in Guangdong can be explained using Ripley's *K* function. The fixed radius method in geometric fractals is further selected to explore the spatial differentiation law of the set of points of ASVs at the regional-scale and municipal-scale. The fixed radius method is essentially a buffer analysis, which needs to set a reasonable initial buffer distance in advance and count the average number of points falling into the circle under each space by continuously expanding the radius value. After multiple operations, the results were more reliable and scientific. As there are no ASVs in Shenzhen among the 21 prefecture-level cities in Guangdong and the corresponding spatial data of the set of points of ASVs were missing, the remaining 20 prefecture-level cities were finally retained. Many manual tests were performed to ensure the operability and rationality of the method. Finally, a fixed radius was selected. That it is the buffer distance range was 5–20 km (taking 5 km as the initial distance, increasing 1 km each time until 20 km, a total of 16 times). The fractal dimension of the ASV spatial distribution in four regions and prefecture-level cities was measured. The calculation formula is as follows:

$$D_R = \frac{\log N_R}{\log R} \tag{3}$$

where D_R represents the geometric fractal dimension obtained using this method, $\log N_R$ is the logarithm of the mean number of points in the circle, and $\log R$ represented the logarithm of the radius of the circle.

3.3.4 Principal component regression

Pearson (1901) proposed principal component analysis. Hotelling (1933) analyzed related structures with principal components and developed a multivariate statistical principal component analysis method. Massy (1965) proposed principal component regression and applied it to empirical research. The background to the practical application of principal component regression is that when there is obvious multicollinearity between independent variables in a study, the results of the ordinary linear regression equation may have significant discrepancies that can not be explained. Therefore, first time, the principal component analysis of each variable should be carried out. The correlation between the extracted main components is zero, which can effectively solve the multicollinearity problem of the original variable. The core idea of principal component regression is to replace the original independent variable with the main component extracted from the original independent variable and then perform regression analysis with the dependent variable.

First, the factor analysis tool in SPSS 26.0 was used for principal component analysis. The Kaiser-Meyer-Olkin (KMO) calculation results and Bartlett spherical test were used as the applicability judgment standards. The results showed that the KMO value was 0.79, and the Bartlett's Test of Sphericity result was also significant ($P < 0.05$), indicating that the correlation between the original variables was strong, which is suitable for factor analysis to extract principal components to crack the existing multicollinearity. Second, the basic variance principle greater than 1 was used to determine the main components; therefore, only the first four were taken. The cumulative variance contribution rate was 75.15%, and the variances of the four principal components were 5.02, 3.76, 1.38 and 1.12, respectively (Table 2).

So, the principal component coefficients could be obtained by dividing the load vector of each principal component by the arithmetic square root of the eigenvalues of each independent component. They were then multiplied by 15 variables, standardized by the *Z*-score using SPSS 26.0, which are the functional expressions of the four principal components. In that setting, this study used the extracted four principal components as new independent variables (there was no correlation between the variables) and took the number of ASVs in each district and county as dependent variables for regression analysis to obtain the principal component regression equation model, as shown in Table 3. Finally, the regression equation of the original independent and dependent variables could be obtained by substituting the expression of the principal component into the regression equation.

4 Results

4.1 Spatial distribution characteristics of ASVs

4.1.1 Spatial distribution pattern

Table 4 shows that the number and proportion differed from one city to another. At the regional-scale, the number and proportion of ASVs in NR were the highest. In contrast, the results were the lowest in ER. Specifically, the number of ASVs in each region varied greatly over the study area. On the one hand, NR accounts for about 37.11%, PRD is 26.00%, and on the other hand, WR record 21.08%, ER is 15.81%. At the same time, the results shed light that, at the municipal-scale, Meizhou had the most significant number of ASVs, with 10.28% of the total. Alternately, Shenzhen did not record any ASVs. Then the cities such as Zhuhai (0.44%), Shantou (2.77%), and Zhongshan (1.27%) record a low proportion.

As can be seen in Fig. 2, the ASVs in Guangdong Province were distributed in multiple patches with an uneven spatial layout. At the regional-scale, ASVs formed a high-density area in the Chaoshan Plain in ER and a secondary high-density area in WR. The distribution of ASVs in PRD was relatively scattered, similar to the mountainous regions of NR. At the municipal-scale, ASVs form high-density areas in the north of Guangzhou mountainous regions, the central part of Jieyang, the west and significant amounts of Shanwei, most of Chaozhou, and the middle and eastern parts of Maoming. Secondary high-density areas were formed in the central and western parts of Meizhou and other places. In addition, ASVs were widely distributed in Shantou and Yangjiang, whereas ASVs were relatively scattered in other cities.

In the study area planting industry, breeding industry, agricultural product processing industry, and leisure agriculture are the main categories chosen according to agricultural production. The planting industry was as high as 84.85%, making it the leading type within ASVs in Guangdong Province, followed by the breeding industry, accounting for a relatively small proportion of approximately 12.87%, while agricultural processing and leisure agriculture characterize a tiny proportion of ASVs, accounting for 1.67% and 0.61%, respectively. To explore the regional differentiation law in space, this study drew a spatial distribution density map highlighting the characteristics and types of ASVs (for a unified standard for comparison, this study set the density value to the same level by taking the mean value) (Fig. 3). It can be seen from the distribution that planting industry ASVs were widely distributed throughout the province. The density value of the Chaoshan Plain in ER was the largest, followed by WR, and the density values of

Table 2 Extraction results of principal component of Guangdong Province, China

Component	Eigenvalue	Percentage variance of initial eigenvalue	Cumulative percentage / %
1	5.02	33.43	33.43
2	3.76	25.08	58.51
3	1.38	9.18	67.69
4	1.12	7.45	75.15

Table 3 Principal component regression model and significance test results of Guangdong Province, China

Type	Unstandardized coefficients (B)	Sig.
Constant	18.36	0.00
Component 1	5.62	0.00
Component 2	1.55	0.00
Component 3	−1.05	0.15
Component 4	−3.29	0.00

Table 4 Number, proportion, and ranking of the agricultural specialized villages (ASVs) in various regions and prefecture-level cities in Guangdong Province, China

Regions	Number	Percentage of the total in province / %	Provincial ranking	Prefecture-level cities	Number	Percentage of the total in province / %	Provincial ranking
Northern Region (NR)	845	37.11	1	Meizhou	234	10.28	1
				Shaoguan	228	10.01	2
				Qingyuan	163	7.16	5
				Heyuan	123	5.40	8
				Yunfu	97	4.26	13
Pearl River Delta (PRD)	592	26.00	2	Zhaoqing	174	7.64	4
				Guangzhou	134	5.88	7
				Huizhou	111	4.87	11
				Jiangmen	63	2.77	16
				Foshan	43	1.89	17
				Zhongshan	29	1.27	18
				Dongguan	28	1.23	19
				Zhuhai	10	0.44	20
				Shenzhen	0	0.00	21
Western Region (WR)	480	21.08	3	Maoming	224	9.84	3
				Zhanjiang	135	5.93	6
				Yangjiang	121	5.31	10
Eastern Region (ER)	360	15.81	4	Shanwei	121	5.31	9
				Jieyang	97	4.26	12
				Chaozhou	79	3.47	14
				Shantou	63	2.77	15

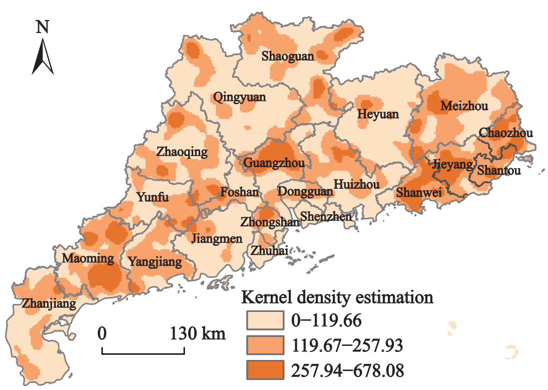

Fig. 2 Spatial distribution pattern of the agricultural specialized villages (ASVs) in Guangdong Province, China

mountainous areas in NR and the plain regions in PRD were relatively low. Breeding industry ASVs were scattered throughout the province. Among them, the density values were relatively high in the southeast of Zhaoqing, the south of Foshan, the north-central part of Zhongshan, and the southeast of Chaozhou. The ASVs for agricultural processing were scattered in the province, mainly in the middle of Shantou, the northwest of Qingyuan, the east of Zhaoqing, the southwest of Yunfu, the east of Maoming, and the north of Zhongshan. ASVs focusing on leisure agriculture were mainly distributed in the mountainous area in the northwestern suburbs of Guangzhou.

4.1.2 Overall spatial distribution mode

In this study, Ripley's *K*-function iteration distance was set as the system's default value ten times. Simultaneously, to ensure the accuracy and reliability of the calculation results, the confidence was determined to be 99%. With increasing distance times, the distribution pattern of the set of points of ASVs reveals specific 'rules' (Table 5). The evidence shows that if 99 groups of points are randomly placed, that is, when the confidence is 99%, ObservedK in the 1st to 10th iterations is greater than ExpectedK; that is, the ASVs in Guangdong Province generally present an aggregation distribution mode within the province. During the first to sixth iterations, the difference (DiffK) between Ob-

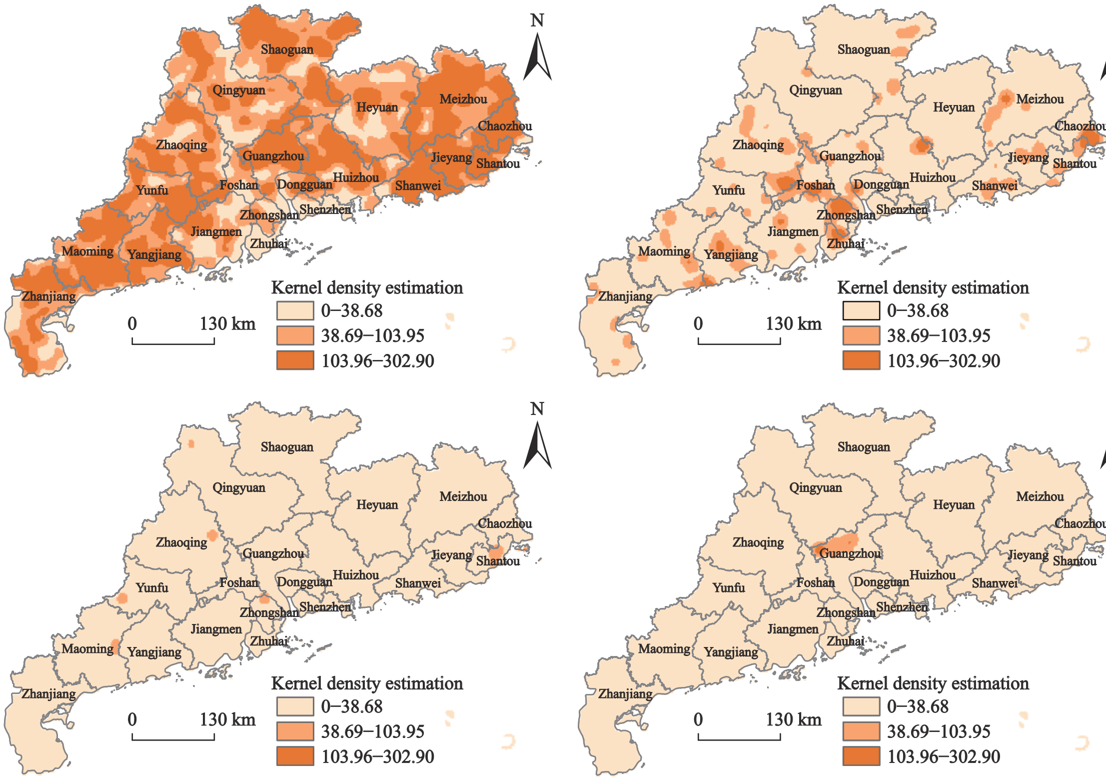

Fig. 3 Spatial distribution characteristics of four categories of the agricultural specialized villages (ASVs) in Guangdong Province, China

Table 5 *K*-function calculation results of the overall spatial distribution mode of the agricultural specialized villages (ASVs) at 99% confidence of Guangdong Province, China

OBJECTID	ExpectedK	ObservedK	DiffK	LwConfEnv	HiConfEnv
1	0.20	0.30	0.10	0.20	0.20
2	0.40	0.55	0.15	0.40	0.40
3	0.60	0.79	0.19	0.60	0.60
4	0.80	1.02	0.22	0.79	0.80
5	1.00	1.24	0.24	0.99	0.99
6	1.20	1.44	0.25	1.18	1.19
7	1.40	1.63	0.24	1.37	1.38
8	1.59	1.81	0.22	1.55	1.57
9	1.79	1.98	0.19	1.74	1.76
10	1.99	2.14	0.15	1.92	1.94

Notes. ExpectedK, usually equal to the distance; ObservedK, generally equal to the actual density.value; DiffK. difference between ExpectedK and ObservedK; LwConfEnv, Low-value confidence interval; HiConfEnv, high value confidence interval

servedK and ExpectedK gradually increases. In the sixth iteration, ExpectedK was approximately 1.20, and ObservedK was approximately 1.44. At this time, DiffK was the largest, at approximately 0.25, and the set of points of ASVs had reached the highest degree of clustering. During the 6th to 10th iterations, DiffK gradually decreased. Therefore, it could be predicted that, after the 10th iteration, with the continuous increase in the number of iterations, ObservedK may become progressively less than ExpectedK, and the distribution of the set of points of ASVs would show a relatively discrete distribution law.

4.1.3 Regional spatial distribution mode

According to the above results, it is known that ASVs in

Guangdong Province generally present an aggregation distribution mode at the provincial scale, based on the fixed radius method in geometric fractals, further calculations of the respective fractal dimensions at the regional-scale and municipal-scale were undertaken to explore the spatial distribution mode of ASVs. At the regional-scale, the fractal dimension of ER was the largest, at 1.57, followed by WR, at 1.52; for NR, the fractal dimension was 1.45, and for PRD it was the smallest at 1.35. Among all prefecture-level cities, Maoming had the largest fractal dimension of 1.61, followed by Guangzhou with 1.48, followed by Yunfu, Yangjiang, Jieyang, Shanwei, Chaozhou, Meizhou, Zhanjiang and so on from high to low, with Zhuhai having the smallest fractal dimension of 0.90 (Fig. 4). Because the calculation results of the fixed radius method reflect the distance attenuation law between points, and the smaller the fractal dimension of the set of points, the more concentrated the distribution is. On the contrary, its distribution is more uniform. Therefore, at the regional-scale, the distribution of ASV points in ER is the most uniform among the four regions, and PRD is the most concentrated. Similarly, at the municipal-scale, the distribution of ASV points in Maoming is relatively uniform, and that in Zhuhai is the most concentrated.

The calculation result of the fractal dimension of the set of points typically corresponds to a specific distribution mode. Under the fixed-radius method, the results between 1.57 and 1.76 are usually clustered in the distribution mode. The results between 1.79 and 1.81 are generally random distribution mode. The value is approximately 1.84, which is typically a uniform distribution mode. This method could easily distinguish the aggregation degree of ASVs at the regional-scale and municipal-scale. Based on the above calculation results, at the regional-scale, the fractal dimension of the four regions was between 1.35 and 1.57, and the maximum was 1.57 < 1.79. Therefore, it could be concluded that the spatial distribution mode of the set of points of ASVs in the four regions of Guangdong Province followed the aggregation distribution pattern, among which PRD was the most concentrated, and ER was the most uniform. On the scale of cities, the fractal dimension of each prefecture-level city was between 0.90 and 1.61, and the maximum was 1.61 < 1.79.

Similarly, it could be seen that the spatial distribution form of the set of points of ASVs of each prefecture-level city in Guangdong Province also followed the aggregation distribution mode, in which Zhuhai was the most concentrated and Maoming was the most uniform. According to the actual situation, the secondary and tertiary industries usually accounted for a large proportion of economically developed areas. Only a few sites focused on developing characteristic agriculture, so ASVs were relatively dense. However, there was also a situation where ASVs were widely distributed in a small area. For example, Zhuhai had the smallest land area among all cities in Guangdong Province, and the number of ASVs was the least, only 10 (except for Shenzhen), eight of which were located in the Doumen dis-

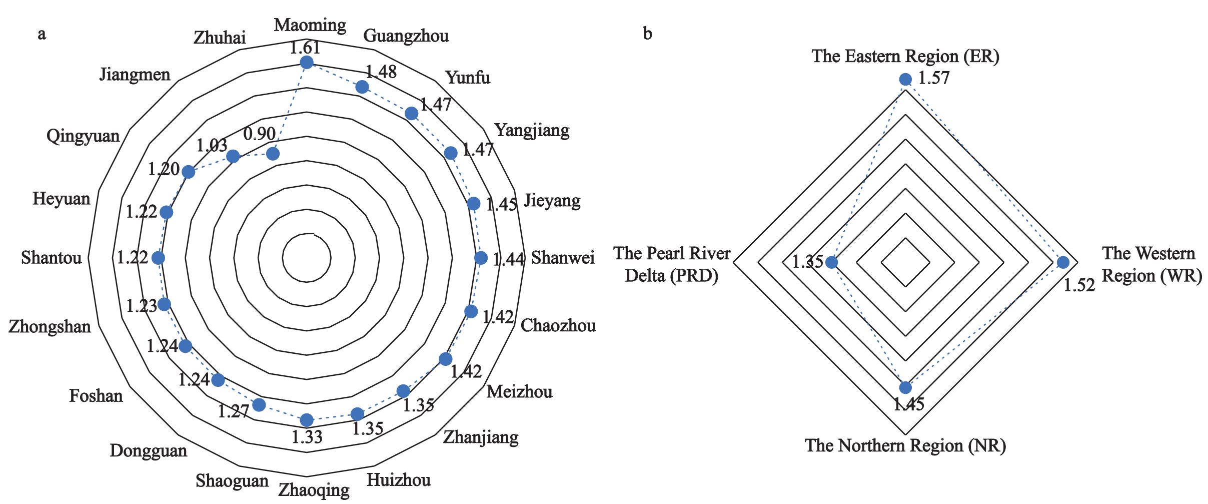

Fig. 4 Geometric fractal dimension of the agricultural specialized villages (ASVs) of prefecture-level cities (a) and regions (b) in Guangdong Province

trict, and five of which were subordinate to the same town (Baijiao town).

4.2 Analysis of influencing factors of the spatial distribution of ASVs

The 15 previously selected indicators were used as independent variables and the number of ASVs in each district and county were used as dependent variables for bivariate correlation analysis to analyze influencing factors. This step focus on comparing the relationship between different indicators and determining the positive or negative correlation (Fig. 5). Among them, only GDP (x_3), distance from main rivers (x_7), and average temperature (x_8) showed a negative correlation with the number of ASVs in each district and county, and the rest were positively correlated. Among the positive correlation factors, a higher degree of correlation was observed for the labor force for primary industry (x_2), area of forest (x_{15}), accessibility resistance to counties and districts (x_{11}), gross output value of farming, forestry, animal husbandry, and fishery (x_4), area of cultivated land (x_{13}), area of garden (x_{14}), rural population (x_1), elevation (x_5), slope (x_6), accessibility to prefecture-level cities (x_{10}), and accessibility to villages and towns (x_{12}). Annual precipitation (x_9) slightly correlated with the number of ASVs in the district and county. Among the negative correlation factors, the correlation between the three indicators and the number of ASVs in each district and county was small, among which the correlation coefficient of GDP (x_3) and average temperature (x_8) was relatively large, and the minimum was the distance from the main rivers (x_7).

The final regression equation obtained from the principal component regression is as follows:

$$y = \sum_{i=1}^{n} b_i x_i + c (n = 15) \quad (4)$$

where b_i is the coefficient of each influence factor (x_i), and c is a constant. The calculation results of b_i and c are shown in Table 6, and the value of b_i is positive and negative, reflecting the specific influence degree and positive and negative effects of various factors on the spatial layout of ASVs.

Among the 15 indicators, 10 had a positive impact on the number of ASVs in each district and county (x_1, x_2, x_4, x_5, x_6, x_{10}, x_{11}, x_{13}, x_{14}, x_{15}). The results show that the rural population (x_1) had the most significant impact,

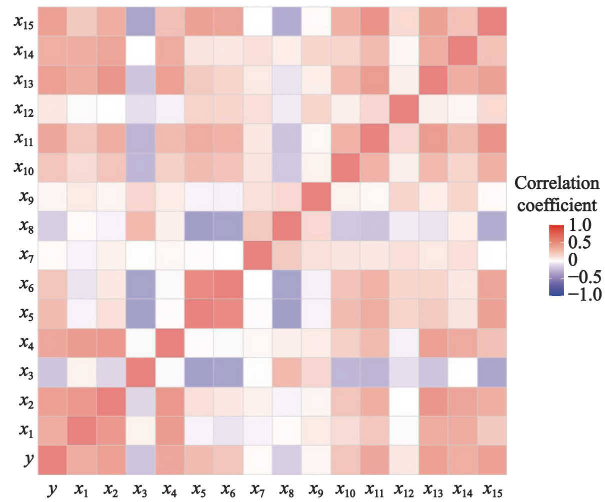

Fig. 5 The correlation between the influencing factors and the number of the agricultural specialized villages (ASVs) in each district and county in Guangdong Province, China

and the area of garden (x_{14}) had the least impact. Five other indicators had a negative impact on ASVs (x_3, x_7, x_8, x_9, x_{12}). This study note that the accessibility resistance value to villages and towns (x_{12}) had the greatest impact, and the average temperature (x_8) had the least impact. Specifically, in terms of economy and population (x_1–x_4), rural population (x_1), labor force for primary industry (x_2), and the gross output value of farming, forestry, animal husbandry, and fishery (x_4) had a positive impact on the number of ASVs in the district and county. At the same time, GDP (x_3) was negative. That is, the greater the rural population, the greater the labor force in primary industry.

In addition, the higher the total output value of agriculture, forestry, animal husbandry, and fishery, the more ASVs, the higher the GDP and the fewer the ASVs, and vice versa. This situation indicated that the rural population, especially the agricultural population, provided a sufficient labor force to form and develop ASVs. The number of ASVs was also higher in areas with better levels of agricultural development. In contrast, the number of ASVs in regions with higher levels of economic growth was generally relatively small. In the dimension of the natural environment (x_5–x_9), elevation (x_5) and slope (x_6) had a positive impact on the number of ASVs in the district and county. At the same time, the distance from main rivers (x_7), average temperature (x_8), and annual precipitation (x_9) were negative. The higher the altitude and the greater the slope, the more ASVs in districts and counties. The farther away

Table 6 Principal component regression results of the influencing factors for spatial distribution pattern of the agricultural specialized villages (ASVs) of Guangdong Province, China

Variable	Coefficient b	Constant c
Rural population (x_1)	1.09E-05	8.18
Labor force of primary industry (x_2)	4.40E-06	
Gross domestic product (GDP) (x_3)	–2.32E-06	
Gross output value of farming, forestry, animal husbandry, and fishery (x_4)	3.54E-06	
Elevation (x_5)	3.30E-06	
Slope (x_6)	2.53E-06	
Distance from main rivers (x_7)	–1.12E-06	
Average temperature (x_8)	–2.73E-06	
Annual precipitation (x_9)	–9.57E-07	
Accessibility resistance to prefecture-level cities (x_{10})	3.51E-06	
Accessibility resistance to counties and districts (x_{11})	3.97E-06	
Accessibility resistance to villages and towns (x_{12})	–3.16E-07	
Area of cultivated land (x_{13})	3.88E-06	
Area of garden (x_{14})	2.37E-06	
Area of forest (x_{15})	4.23E-06	

from main rivers, the higher the average annual temperature and the more precipitation, the fewer ASVs in districts and counties, and vice versa. It could be seen that some districts and counties with high altitudes and large slopes had more ASVs, and the two indicators of temperature and precipitation also had a negative effect on the number of ASVs in districts and counties.

Consequently, unlike traditional agricultural production, which relies heavily on water sources, the current layout of ASVs does not reflect a significant water source orientation. In the dimension of traffic accessibility (x_{10}–x_{12}), accessibility resistance to prefecture-level cities (x_{10}) and districts and counties (x_{11}) had a positive impact on the number of ASVs in districts and counties. In contrast, accessibility resistance to villages and towns (x_{12}) had a negative effect. The greater the resistance value to prefecture-level cities, districts, and counties (the worse the accessibility), the more ASVs there are. Or, the more significant the resistance value to villages and towns (the worse the accessibility), the fewer ASVs there are, and vice versa. It could be seen that the spatial layout of an ASV was closely related to its adjacent townships, and its prefecture-level cities, districts, and county administrative centers did not have a significant radiation impact on ASVs.

Moreover, the accessibility conditions did not strictly limit the formation and development of ASVs. In the dimension of agricultural resource endowment (x_{13}–x_{15}), the area of cultivated land (x_{13}), garden land (x_{14}), and forest land (x_{15}) had a positive impact on the number of ASVs in the districts and counties. The larger the area of various agricultural lands, the more the ASVs, and vice versa. This context indicated that land resources were closely related to the spatial layout, form, and scale of ASVs, and high-quality agricultural resource endowment was an essential condition for their formation and development.

5 Discussion

5.1 The role of natural resource endowment in the development of ASVs

For a long time, different regions in Guangdong Province have to maintain their agricultural production traditions and cropping practices and develop characteristic regional industries, enabling the continued production of high-quality agricultural products. In addition, with technological progress and increasing specialization and scale, typical and representative villages have formed ASVs. To a certain extent, the innate differences in natural background conditions and the differences in future development paths gave rise to regional differentiation of the layout of ASVs in the province. Taking the spatial distribution of ASVs at the regional-scale as an example, the overall number of ASVs in NR is the highest. The general layout in the region is relatively scattered and relatively concentrated locally.

In contrast, the overall number of ASVs in ER and WR is relatively low, but the spatial distribution is more uniform. NR is an essential part of Nanling Mountains. The dominant topography is mountainous, concentrated, and contiguous land seems scarce, the difference in altitudes is rather large, and the stereoscopic climate is relatively significant (Fu, 2017). Nevertheless, the mountainous areas of NR are rich in various high-quality agricultural products from both cropping and animal husbandry. The farmers adhere to the concept of being green, organic, and pollution-free on their farms, planting off-season vegetables in summer and autumn in alpine areas. Or, ER comprises plains, mountains, and hilly terrain, with more people and less land. The climate in this region is mild, allowing for all-season cultivation. In addition, the area has ancient agricultural traditions which are substantial and far-reaching, and local farmers attach great importance to production, are good at farming, and pass on their traditional agricultural practices from generation to generation, such as intensive cultivation and interplant. Their rich cultivation experience comes from historical continuity and encompasses many crops, such as rice, tea, fruits, and vegetables. WR is located in the tropical monsoon climate zone, with a short crop growth cycle that includes extensive cultivation of tropical fruit, and is thus an important fruit production base for the country. In addition, the region has a long history of vegetable production transported to the north of China, which is also the main producing area. Currently, the agricultural economy in Guangdong Province has generally shown a trend of moving to the southwest, and WR has gradually become more advantageous for specialized regional agricultural production (Chen et al., 2014).

This study also presents a preliminary study on the driving force behind the spatial distribution mode of ASVs in Guangdong Province. The results from assessing the relevant indicators in the two dimensions of the economy and population and agricultural resources are more conventional. In comparison, the research results in the two dimensions of the natural environment and traffic accessibility are thought-provoking. It is worth mentioning that ASVs across the country are located in areas with superior terrain and resources (Cao et al., 2020). At the same time, ASVs in Guangdong Province shows the characteristics of high altitude, high slope, and close water sources, with less dependence on external traffic accessibility. It can be seen that the negative impact of hills and mountainous terrain on the agricultural specialization rate has been gradually weakened, with water resources and traffic accessibility no longer being the decisive factor for the formation and development of ASVs (Zhou and Li, 2015; Zhou and Wu, 2021). Remote areas, such as mountainous areas in NR, have certain advantages in agricultural resources and a better ecological environment. Unique and competitive agricultural products have become their primary economic resource (Li et al., 2012a; Huang, 2021). Among them, Daye tea from Liannan County, stone carp from Ruyuan County, osmanthus fish from the Qingxin District of Qingyuan, and golden pomelo from the Meixian County of Meizhou. These items have been selected as national agricultural indicator products, generating more possibilities for developing ASVs. It can be seen that high altitudes, large slopes, and poor traffic accessibility do not restrict the formation and development of ASVs.

5.2 The relationship between the market demand and the development of ASVs

Ke et al. (2009) divided the development model of regional characteristic agricultural industries in Guangdong Province into four categories: ecological resource type, market consumption type, efficiency scale type, and efficiency industrial chain type, corresponding to the four provincial regions, namely NR, PRD, WR, and ER. The development of ASVs relies heavily on their inherent resources and conditions (Wan et al., 2009; Gao and Shi, 2011). Resource endowment, geographical location, production and cropping practices, economic development level, and other factors significantly impact farmers' degree of specialization. These factors also result in significant differences in the interaction ranks between different villages (Li et al., 2013). It should be noted that not all local resources and advantages are conducive to improving specialized production in the villages (Wu and Li, 2017). Generally, crops with vital spillover attributes and high consumption rigidity are evenly distributed in the region, such as vegetables, grains, and oil.

In contrast, cash crops such as fruit and tea are grown according to the allocation of resources, location advantages, and other natural conditions and meet market positioning and consumer needs. The region has a substantial industrial agglomeration (Huang and Zhong, 2017). In recent years, the influence of market factors on ASVs has become increasingly prominent, which has also promoted the emergence of the comparative advantage of agricultural resources in the province, especially in PRD, which has a developed economy, dense population, and high consumption demand (Zhou and Li, 2015).

PRD is dominated by estuarine alluvial plains with fertile soil and a good combination of rainfall and temperature. Compared with ER, NR, and WR, PRD had an early and absolute advantage in agricultural production and took the lead in development. Since ancient times, traditional agricultural production and management modes for rice and mulberry fishponds have continued. The area is labeled the 'land of fish and rice' and a commodity grain base in South China. With the deepening of reform, opening up and urbanization as a frontier, PRD has developed rapidly, with the industrial structure also being transformed and upgraded. The original traditional agricultural production has gradually transitioned to modern processing, manufacturing, and service industries; the proportion contributed by the primary sector has been declining, and the scale of the agricultural output has been gradually reducing (Chen et al., 2014). Therefore, the number of ASVs in the region is relatively small compared with that in NR, and the distribution is uneven. These settlements are mainly concentrated in the mountainous area in the north of Guangzhou, which provides a good foundation for agricultural development. In recent years, to meet the consumption demand for high-quality, characteristic agricultural products and the experience demand for leisure and entertainment space of consumers in PRD urban agglomeration, urban-suburban ASVs came into being. According to the regional agricultural resources and characteristic industries, these ASVs strongly support urban agriculture's development, including high quality, high efficiency, and high added value cash crops that meet market demand. This context significantly impacts the formation and development of ASVs and has also achieved good social and economic benefits. However, the growth of agricultural specialized markets in Guangdong Province lags and has become a significant problem, restricting the development of characteristic agriculture in ASVs; thus, this issue requires future attention (Shi, 2010). In short, in the formation and development of ASVs, the role of natural resources has gradually weakened. Socioeconomic factors play an increasingly important role as an emerging force driving further development (Li et al., 2012b; Chen et al., 2014).

5.3 Role of agricultural policies and technical facilities in the development of ASVs

Implementing agricultural policies laid the foundation for the formation and development of ASVs, creating a conducive macro-environment. In recent years, Guangdong Province has experienced comprehensive agricultural modernization. Industrial development has been oriented around modern agriculture's development goal. This situation includes building several intensive and modern agricultural demonstration parks with precise main functions, strong driving forces, scientific and technological demonstrations, and agricultural tourism. This context has been achieved through adhering to the government's guidance which supports leading agricultural enterprises and specialized farmers' cooperatives. This way, distinctive industrial belts in different provinces' regions have gradually been implemented.

Guangdong Provincial authorities have successively issued various other support policies related to ASVs, providing financial and tax support fees and land preference for the development of OVOP. For example, in the past, the financial input for the ASVs was mostly a reimbursement system. Currently, some areas are directly allocated to the implementation subject by the county's finance department. The decentralization of authority gives agricultural enterprises greater autonomy. The policy preference and support of local governments are also indispensable. Taking the prefecture-level city of Guangdong Province as an example, Meizhou is a typical mountainous agricultural city with a long and unique farming history. It has permanently attached far more importance to agriculture than other cities. In recent years, the policy support for OVOP has been increasing, the development of ASVs in the region is in full swing, and the scale is expanding (Gu et al., 2021). The spillover effects radiating to the surrounding rural areas are also increasing. Guangzhou has vigorously promoted various agricultural production support policies such as awards instead of subsidies, brand certification, scientific and technological development, chemical fertilizers and pesticides, and agricultural financial projects, providing advantageous development conditions and policy support for implementing OVOP (Lu et al., 2020).

Indeed, the growth process of ASVs is inseparable from modern agricultural production technology. The rapid evolution of related technologies has effectively stimulated the energy and vitality of ASVs. Through technological innovation, the varieties of agricultural products can be explored and improved, the intensive processing capacity of the leading agricultural products can be enhanced, and the quality and efficiency of agricultural products can be promoted. Innovations and optimization of packaging technology can also effectively solve problems in distributing fresh agricultural products. For example, some countries reduce losses by increasing standardized fruit and vegetable turnover baskets. The future development of ASVs is also closely related to digital agriculture, including a series of specific measures, such as 5G+ agricultural big data service platforms, the introduction of intelligent equipment such as unmanned aerial vehicles (UAVs) and robots, and the comprehensive integration of remote sensing (RS), GPS, and GIS technology to carry out real-time monitoring, accurate positioning, and the dynamic analysis of agricultural production. These measures help realize agricultural production management's standardization, refinement, and intelligence. In recent years, Guangdong Province has also advocated that implementing OVOP should be both characteristic and green, focusing on improving green ecological technology, agricultural technology, and modern information technology and providing intelligence support for developing characteristic industries. It also supports the development of e-commerce marketing by providing information directly to the villages and households. It explores and promotes the concept of 'One Village, One Product, One Store'. In addition, relying on big data to systematically analyze the sales of agricultural products in various regions can help direct the rational distribution of target markets in the future.

The formation and development of ASVs should focus on constructing agricultural facilities. Rational allocation of agricultural facilities and resources effectively improves agricultural production efficiency. Although the overall efficiency of agricultural resource allocation in Guangdong remains high, regional development is particularly unbalanced. The efficiency of agricultural resource allocation varies greatly, with the total efficiency value of NR being much lower than that of the other three regions (Yao and Zhu, 2019). The regional agglomeration effect of agricultural facilities in the province is also significant. They are generally concentrated in PRD, which has a relatively well-developed economy. The development scale of agricultural facilities in PRD urban agglomeration is considerable. One example is that it has the most plastic greenhouses and large multi-span greenhouses in the province, helping Guangzhou to rank first in the province in terms of the number and scale of agricultural facilities (Ye et al., 2021). This context provides good support for the development of ASVs. However, most agricultural production in the mountainous areas around PRD is still dominated by individual farmers with less investment in agricultural machinery and facilities. Relevant studies highlighted that this situation leads to the lagging development of the agricultural economy and a low level of specialization and modernization in the agricultural industry, which can hinder the development of ASVs (Deng and Wan, 2020).

5.4 Role of the stakeholder participation in the development of ASVs

'Endogenous development' is the basic principle of implementing OVOP in many countries worldwide. It considers the three key factors: self-reliance, local capacity, and human resource development (Denpaiboon and Amatasawatdee, 2012; Mukai and Fujikura, 2015; Schumann, 2016; Thanh et al., 2018). Moreover, endogenous development emphasizes the importance of participation. Currently, the organizational mechanisms of ASVs in China are mainly driven through promotion by local governments, inputs by industrially capable people, and collaborative planning by village communities (Xia, 2020). In the initial stage, capable people play a core role in the development process, which can be expedited through government support (Gao and Shi, 2011). Li et al. (2009) believe that the formation and evolution of ASVs can be attributed to four aspects: imitation innovation, network connection, economies of scale, and division of labor. Bai and Qiao (2015) found that in different stages of the formation of ASVs, the core driving factors gradually change from blood tie and geographical closeness to work relation. In short, the formation and development of an ASV in a region are affected by multiple factors. The various aspects can be roughly divided into internal and external by combining and summarizing previous research results. The internal factors are mostly terrain and climate, natural resources, geographical location, accessibility conditions, economic foundations, historical and cultural traditions, cultivation and production practices, capable people and non-governmental organizations, the willingness of farmers, and innovation ability. The external factors are primarily urban-rural relations, regional environment, institutional policies, financial support, market demand, science and technology, development opportunities, social capital, media publicity, and accidental factors.

Specifically, with the continuous acceleration of the urban-rural integration process and the optimization of regional development in China, during the development of ASVs, local governments should first examine the status quo of each village and clarify its advantages and disadvantages. For villages with relatively superior natural environmental conditions, agricultural resources, adjacent markets, and suitability for large-scale and specialized production, appropriate industrial layout models and development plans can be formulated. In addition, support and encourage leading enterprises, large specialized households, skilled farmers, rural brokers, family farms and other new business entities to establish different types of specialized cooperative organizations and carry out standardized construction. By guiding leading enterprises to develop a stable production and marketing relationship through contract or cooperative systems with individual farmers or specialized cooperatives, there will be risk-sharing and common interests which will help with the integration of production and marketing. Among them, the willingness to participate and the role of demonstrations are essential. Innovation ability has also become a critical factor in the sustainable development of ASVs. At the same time, based on implementing various national agricultural policies, local governments have also issued particular preferential policies suitable for regional development, regularly increasing financial investment and support, improving infrastructure, and supporting innovations in agricultural production. This context is intended to assist with expanding the scale of production, creating characteristic brands, and improving product quality. The publicity and reporting of mainstream platforms can also extend the external attraction and brand influence of characteristic agricultural products. In addition, ASVs also need to keep pace with market demand, seize development opportunities, and strive to create a comprehensive agricultural development model based on resources and accessible markets. More, this process needs available benefits and appropriate science and technology-driven innovations, with leading industries as the core, agricultural enterprises as the leader, production bases as the carrier, and specialized cooperatives as the practical demonstration models (Fig. 6).

Therefore, focusing on brand building, improving infrastructure, increasing investment in science and technology, prolonging industrial chains, and promoting industrial integration are essential for establishing new ASVs and growing existing ASVs. For the regional mode for future development of ASVs, scattered farmers in the region can be encouraged and guided to join agricultural cooperatives, participate in group development, further refine the agricultural division of labor and promote the development of industrial clusters in the region (Pu and Jiang, 2013; Qiao and Yang, 2013). It is essential to clarify the advantages and disadvantages of different areas, adjust the regional development strategy in response to actual conditions of ASVs, optimize traditional industries, strengthen characteristic industries, and expand emerging industries.

6 Conclusions

Based on the list of the first and second batch of 'One Village One Product, One Town One Industry', identified by the Department of Agriculture and Rural Development of Guangdong Province, this study examined 2277 ASVs as the research subject. It comprehensively integrated a variety of quantitative analysis methods. The spatial differentiation and distribution patterns of ASVs in the province were depicted and measured, and the impact of multiple factors on their formation and development was explored. The main conclusions are as follows.

The number of ASVs is not balanced in space, and there are certain differences between regions and prefecture-level cities. Specifically, among the four regions, NR has the largest proportion, and Meizhou has the largest proportion among all the prefecture-level cities.

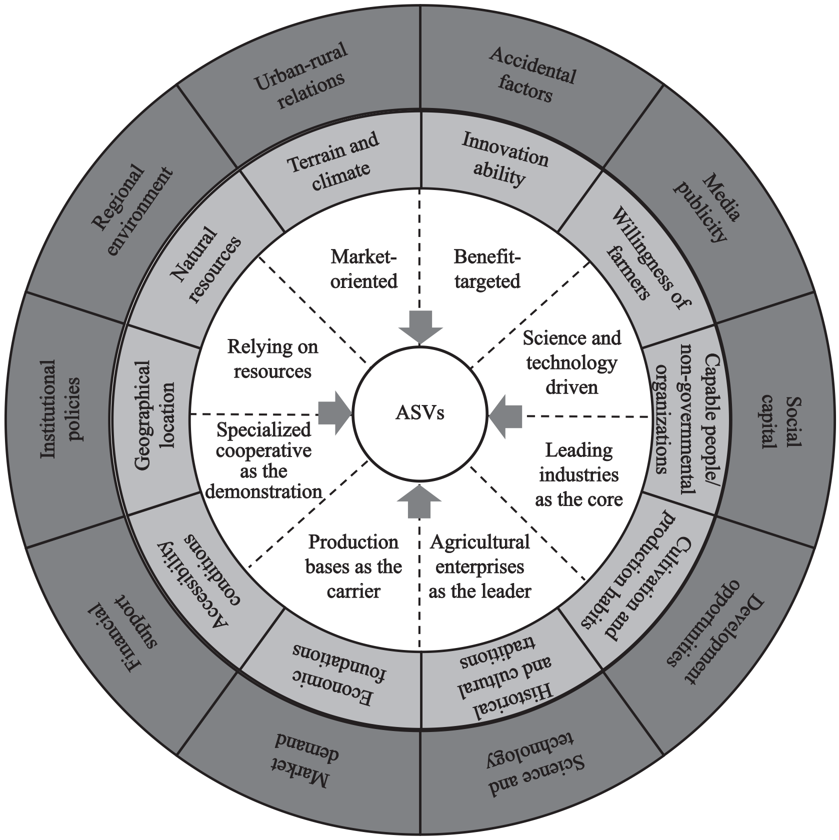

Fig. 6 Comprehensive influence mechanism driving the formation and development of agricultural specialized villages (ASVs)

From the perspective of the spatial distribution pattern of ASVs in the province, the ASVs are distributed in multiple patches, and are concentrated and distributed in the Chaoshan Plain Area in ER at the regional-scale. At the municipal-scale, high-density areas have been formed in the mountainous areas in the north of Guangzhou and the east of Maoming. At the same time, the spatial distribution mode of ASVs obeys the aggregation distribution mode on the whole under these three scales. Specifically, at the-regional scale, ER is the most uniform, and PRD is the most concentrated. At the municipal-scale, Maoming is the most uniform, and Zhuhai is the most concentrated. In addition, according to the results of the industrial division, ASVs in Guangdong are dominated by the planting industry and supplemented by a small proportion of the breeding industry, as well as limited agricultural product processing and leisure agriculture.

In conclusion, the formation and development of ASVs may be affected by various internal and external factors. Natural resource endowment and geographical location conditions have laid the foundation for its initial formation. The unique agricultural production traditions and planting habits of various regions for a long time have further promoted the regional differentiation. Market demand has gradually become a key factor, especially in PRD and other metropolitan areas. At the same time, other factors such as active and powerful policy guidance, good technological innovation environment and advanced and complete agricultural facilities in the region have also played a role in promoting its formation and development to a certain extent, or become the differentiation factor at present and in the future. In addition, the coordinated participation of multiple entities under the government's leadership can effectively promote the comprehensive establishment of the development system. In conclusion, during the formation and development of ASVs, the constraints of natural environmental conditions gradually weakened, and the role of social and economic factors was increasingly strengthened.

Research related to ASVs is comprehensive and involves economics, geography, management, sociology, and other disciplines. This study is only a preliminary exploration of the spatial layout and influencing factors of ASVs in Guangdong Province and has the following limitations: 1) The research object lacks regional contrast. It only focuses on the development status of ASVs in Guangdong Province. It does not compare with different development modes in other regions in China, such as Henan Province, where ASVs are relatively maturely developed. 2) The research lacks diversity, as researchers tend to focus on their primary concern, in this case, ASVs, and not investigate other types of specialized villages in the region, such as industrial and service-oriented villages. 3) The research perspective is not dynamic. The main concern is the spatial layout and influencing factors of ASVs within the OVOP programme in Guangdong Province, without time series analysis, so the temporal and spatial evolution features of the formation and development of ASVS need to be further explored.

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