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The multidimensional development index of new agricultural business entities in mountainous and hilly areas based on the projection pursuit evaluation model: evidence from household survey data in the modern agricultural Park of Jiangjin district, Chongqing

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China's gradual transition from traditional agriculture to modern agriculture has allowed land factors with comparative advantages in the countryside to be identified, which, in turn, has promoted the two-way flow of urban and rural resources, leading to the reallocation of various resources such as land, labor, capital, and technology. Completely realizing the potential of various factors is dependent on forming a beneficial cycle of talent, land, capital, and industry by new business entities. The natural and economic conditions of agricultural resources vary greatly in China, especially in hilly and mountainous areas. Therefore, it is essential to promote the high-quality development of new agricultural businesses in these areas, which will accelerate the construction of modern agricultural management systems and encourage rural revitalization. Furthermore, exploring the multi-dimensional development potential of different types of business entities will stimulate the growth of new agricultural businesses. This study presents a thorough system for evaluating development potential. The system consists of five dimensions: development potential, economic performance, social performance, ecological performance, and development prospects. The projection tracing model is employed to evaluate the development potential of diverse types of business entities. Based on the evaluation results, the development potential of new business entities is categorized according to the village scale in 68 sample villages. The results show the following: (1) The four types of new business entities with the greatest potential for development were agricultural enterprises, followed by farmer cooperatives, and finally large farmers and family farms. From the perspective of industrial types, the agricultural enterprises with the greatest development potential were fruit and vegetable agricultural enterprises; the farmer cooperatives with the greatest development potential were comprehensive farmer cooperatives; the large farmers with the greatest development potential

were grain and oil farmers; and the family farms with the greatest development potential were comprehensive family farms. (2) Differences in the dimensions and comprehensive projection values of assorted new business entities were present. The comprehensive projected values in descending order were agricultural enterprises (1.0051), farmer cooperatives (0.8135), large farmers (0.6513), and family farms (0.5972). New corporate entities with distinct potential exhibited variations in high-density locations, showcasing either singular or numerous agglomeration centers. (3) The villages in the study area were divided into five types based on their development potential: low, relatively low, normal, relatively high, and high, accounting for 29.41, 16.18, 27.94, 16.18, and 10.29% of the total villages, respectively. The results of this study demonstrate that, to strengthen the long-term sustainable development capacity of new business entities, it is necessary to recognize the strengths and weaknesses of developing new businesses and promote differentiated growth in various regions.

KEYWORDS

new agricultural business entities, development potential, spatial differentiation, the projection pursuit model, hilly and mountainous areas

1 Introduction

With the continuous development of China's agricultural and rural economy, the new agricultural business entities represented by large agricultural professionals, family farms, farmers' cooperatives, and agricultural enterprises have increasingly shown their vitality and potential for development and have become the core subjects of modern agricultural development in China. New agricultural business entities have emerged under the new historical conditions for agricultural modernization (Zhao, 2022). Developing diverse new agricultural business entities has become a strategic decision to expedite agricultural modernization, which plays a crucial role in the supply-side structural reform of agriculture and the growth of moderate-scale agriculture. The development of land flow transformation will radiate and drive new agricultural business entities (Ruan et al., 2017, 2022), making the long-term idled and deserted rural land to be rapidly activated (Zhang et al., 2022; Goswami et al., 2023). At the same time, this alleviates rural young and middle-aged labor loss, which is central to determining who will farm the land and to increase the income of farmers.

The wave of cooperative economy first arose in the early nineteenth century in France and England under idealistic socialism. In the middle of the nineteenth century, the cooperative economy continued to develop in all countries and become significant economic organizations in society. Based on idealistic socialism, Marx proposed scientific socialism, in which the idea of cooperative economy became the basis for subsequent research (Liu and Li, 2022). Many foreign scholars are currently focusing on the economic impact of new business entities on poverty alleviation. New business entities have the potential to reduce poverty, benefiting larger farms and remote areas in particular (Gkiza and Nastis, 2017). Furthermore, cultivating new management entities can be a valuable strategy for addressing the challenges faced by farmers, such as outdated production techniques, low efficiency, and poor product quality. This approach also contributes to preventing farmland abandonment and reducing abandonment rates. When faced with the lack of economic development power, new management entities often take the way of reducing the cost of production materials, giving full play to the brand effect on the basis of the importance of product quality, and increasing the added value of products (da Silva and Gameiro, 2022). Thus, new agricultural business entities have been growing steadily, which has led to a continuous drive for development. In recent years, a new pattern of integration and development has emerged, involving a mix of agricultural enterprises, large-scale planters, livestock farmers, farmer's professional cooperatives, and family farms. This diversified operational system continuously stimulates the development vitality of new agricultural business entities. Due to the varying topographical conditions and regional development limitations, the comparative advantages of the development of new agricultural business entities are uneven. There are significant regional disparities in economic performance and development prospects. Identifying the sustainable development capabilities of various new business entities is indeed crucial for tailoring strategies to local conditions and fostering diversified agricultural businesses effectively. When examining how new businesses can thrive in the long term, 78 different factors were identified across five key areas: economics, the environment, social impact, organizational structure, and trade relationships, all within the agriculture sector.

According to the theory of comparative advantage, the new agricultural management entities exhibit a greater degree of specialization intensification and agricultural modernization compared to traditional small farmers. Consequently, they are able to effectively utilize their comparative advantages. These entities have the functions of driving retail households, organizing large households, connecting enterprises, and connecting markets (Zhan, 2023). According to the theory of a cooperative economy, in Marx's social economics, when the social economy develops to a certain stage, members will spontaneously form economic organizations, which are called cooperative economy. Therefore, the form of a cooperative economy can concentrate more resources, serve more members, and promote the development of each member. The essence of the new agricultural management entity is the most effective form of collective

economy (Song, 2023). The theory of agricultural modernization emphasizes the shift from traditional to modern agriculture through different methods and processes. The modernization of agriculture involves upgrading production methods, technology, workforce, organization, management, and infrastructure. The end goal is to attain high productivity, superior quality, and optimal resource utilization in agricultural production, resulting in a well-developed agricultural sector and enhanced income for farmers. Agricultural modernization is the process of developing and transforming traditional agriculture to modern agriculture (Zhang, 2022). Therefore, there is a need to develop and cultivate new agricultural business entities.

Most of the existing studies focus on evaluating the development level, efficiency, and sustainability of multiple or single types of new agricultural business entities, a certain type of agricultural system, or a single industry by constructing an evaluation index system using a variety of methods (Zhang, 2022). Notably, there are differences in the construction of the evaluation index system. Using an evaluation system of the development level of new agricultural management subjects based on four aspects, namely, the level of agricultural output efficiency, the level of development of family farms, the level of development of farmers' cooperatives, and the level of development of agricultural leading enterprises (da Silva and Gameiro, 2022; Ruan et al., 2022), it can be observed that the new agricultural management subjects are in a stage of transition from the primary agricultural modernization to the basic agricultural modernization (Li and Yu, 2020). An evaluation based on resource integration, environmental improvement, industrial development, and efficiency enhancement (Wang et al., 2018) reveals that agribusinesses perform the best in terms of integrated effects, followed by cooperatives, and then family farms the worst (Yang and Li, 2021). An evaluation based on the four dimensions of organizational production capacity, market operation capacity, service to society, and profitability reveals that the highest level of development is found in the central region (Ren and Xue, 2018). Previous studies have shown that family farms have a high level of economic efficiency and a good level of social efficiency, but a less than satisfactory level of ecological efficiency, and a medium to high level of overall efficiency (Chen et al., 2022). Furthermore, there are differences in the factors influencing the higher efficiency of farming family farms compared to growing family farms and mixed family farms, where production subsidies may have a negative impact on efficiency (Balezentis et al., 2014). There is scope to improve the technical and scale efficiency of China's new agricultural business entities (Li et al., 2022). However, there are scarce studies on the development potential of various types of new agricultural business entities (Antunes et al., 2017). The evaluation methods are also diversified, including the comprehensive evaluation method (Guo and Zhou, 2016), factor analysis (Du, 2015), entropy method (Yang and Li, 2021), and analytic hierarchy process (Li and Yu, 2020; Meng, 2022), and there are also issues in relation to the use of a single method, objective empowerment, and subjective evaluation. The development potential of different types of new agricultural business entities in different regions varies. Through a comprehensive evaluation of the development potential of new business entities, this study explores the efficiency and potential of various new agricultural business entities in the mountainous and hilly areas in the modern agricultural park in Jiangjin District of Chongqing. The study also identifies the spatial distribution of the business entities and the development potential types of new business entities in each village. This research may offer guidance on the differentiated cultivation of new business entities in the region, enhance sustainable development, and achieve agricultural modernization.

This study focuses on the towns within the modern agricultural park in Jiangjin District of Chongqing to evaluate the development potential of new agricultural business entities using survey data collected from these entities. The projection pursuit model is used to assess the development potential of various types of business entities in hilly and mountainous areas by creating a comprehensive evaluation system that considers five aspects: development endurance, economic performance, social performance, ecological performance, and development prospects. Exploring the spatial pattern of the development potential of new agricultural business entities in the study area and then screening the strength of regional development potential can provide a reference for exploring the development status and future development potential of business entities and enhancing the development level of business entities.

2 Materials and methods

2.1 Study area

The study was conducted in the Jiangjin Modern Agricultural Park in Chongqing, southwest China, within a hilly and mountainous region (105°57′20″–106°15′20″E, 28°50′10″–29°18′20″N) (Figure 1). The Modern Agricultural Park consists of seven towns, namely, Ciyun,

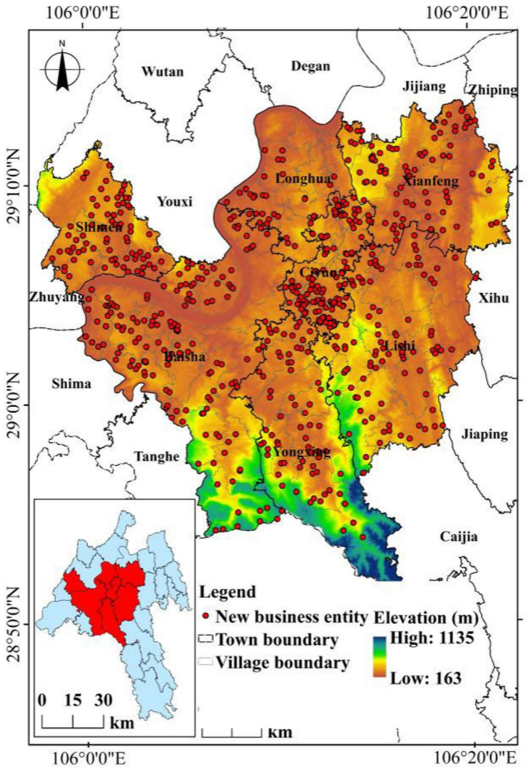

FIGURE 1
Location and elevation of the study area and the distribution of new agricultural business entities.

Longhua, Xianfeng, Lishi, Yongxing, Baisha, and Shimen, and 68 administrative villages. It is predominantly characterized by hilly and mountainous areas, covering a total area of 90.55 hm^2, with an altitude range of 163 m to 1,135 m, with higher terrain in the south and lower terrain in the north. In 2023, the total output value of agriculture, forestry, animal husbandry, and fishery in 7 towns reached 8.23 billion yuan, accounting for 41.32% of the total output value of agriculture, forestry, animal husbandry, and fishery in the entire Jiangjin district. The average *per capita* disposable income of rural permanent residents was 42,364.21 yuan, which was 520.28 yuan higher than the average income of the entire Jiangjin District. The sown area of crops was 54,296.4 hm^2, accounting for 36.04% of the total sown area of crops in Jiangjin District. As of December 2023, there were 724 new agricultural business entities in the study area, including 128 agricultural enterprises, 153 farmers' cooperatives, 211 family farms, and 139 large farmers.

2.2 Data sources and evaluation model construction

2.2.1 Data sources

The data used in this study include natural geographical data, socio-economic data, and survey data of Jiangjin District. The township boundary data of Jiangjin District are derived from the Planning and Natural Resources Bureau of Jiangjin District, Chongqing. Digital elevation model data with 12.5-m resolution come from the research group. Socio-economic data are mainly derived from the 2021 Statistical Yearbook released by the Jiangjin District People's Government. The survey data are mainly derived from the 24-day participatory rural assessment conducted by the research group in July 2020 and July 2021. Based on the list of agricultural enterprises, farmers' cooperatives, family farms, and large farmers registered as industrial and commercial businesses as of December 2020 provided by the Agricultural Economic Station of Jiangjin District Agricultural Commission, including the newly registered and deregistered new business entities. In the field investigations, we held centralized talks with town and village cadres, conducted field surveys and telephone interviews with the recommended typical new business subjects, and finally obtained sample data on the normal operation of new business subjects in the study area. The data covered 68 villages in 7 towns of Ciyun Town, Longhua Town, Xianfeng Town, Lishi Town, Yongxing Town, Baisha Town, and Shimen Town, with a total of 408 valid questionnaires.

Using the data derived from the previous survey, and oriented to the "industry type," the core towns were extracted from the core area of the demonstration park, and then sample villages were extracted from the core towns using a stratified sampling method, which reflects the gradient of the size of the land transfer, the development of industry, and the diversification of subjects. The sample villages reflect the gradient of land transfer scale, level of industry development, and the diversification of new agricultural business entities. Finally, we identified typical new agricultural business entities in the sample villages based on industries with advantageous characteristics and basic industries, such as large-scale land operations, years of operation, and operating efficiency. Next, we conducted land parcel surveys for the land transfer areas of these newly identified business entities. This research included a centralized discussion and exchange, questionnaires, telephone surveys, and field visits combined way, with specific cadres and masses involved in the promotion of rural industrial revitalization. The cognitive research study involved information collection from towns, discussion and exchange of ideas among village and town cadres, the main body of the questionnaire survey, and the representative of the industrial base inspection. First, information was collected at the town level to understand the overall situation of new business entities and their industrial development within the town. Concurrently, discussions, exchanges, and questionnaire surveys were conducted by every village cadre to identify the dominant industries and their spatial distribution. Next, in-depth information on farming practices was collected through surveys involving 2–3 representative new agricultural business entities from each village in typical industries. Based on this information, the participatory rural appraisal was conducted through a combination of semi-structured interviews and questionnaires, focusing on the management, operation, or technical leaders of the business entities, to obtain attribute data of the business entities and the development of the industry. Survey information for business entities includes land transfer scope, land price, industrial layout, family capital composition, land input–output, and scale management preferences. Furthermore, comprehensive information about the park's development was obtained through engagement with community members such as the village secretary, village director, village accountant, village chief, president, senior farmers, and other informed individuals. The surveys covered aspects such as land consolidation, farmland infrastructure construction, financial support, agricultural breeding mode, the average input and output levels of various crops, the market prices of agricultural products and materials, the land transfer mode, and performance outcomes.

2.2.2 Evaluation system construction and index selection

Combined with the actual situation of this study, an index system (Table 1) was developed. This covered the following five aspects: development endurance, economic performance, social performance, ecological performance, and development prospects, to evaluate the development potential of new agricultural business entities. The main basis for the selection of the layers of criteria in this study is the 'New Agricultural Management Entity Development Index Survey (I–VI) Report' issued by the New Agricultural Business Entity Research Group of China Economic Trends Research Institute of Economic Daily. The index layer is determined according to the following three aspects: current development characteristics of new agricultural business entities in the study area, the government's expectations for the future development of new agricultural business entities, and the relevant indicators identified by scholars in the field on the development capacity evaluation of new agricultural management entities (Gen, 2017; Ruan et al., 2017; Ren and Xue, 2018; Tagliapietra et al., 2019; He and Li, 2021; Ruan et al., 2022). The development endurance dimension includes basic conditions such as human capital, corporeal capital, and information technology, which play a supporting role in the development of new agricultural business entities and provide a basic guarantee for the development of new agricultural business entities (Gkiza and Nastis, 2017; Maini et al., 2021). Economic performance refers to the capacity of new agricultural business entities to use their own resources and conditions to create economic value, including solvency, asset management ability, profitability, and financial credit. Social performance reflects the participation of farmers in the new agricultural business entities

TABLE 1 Evaluation index system for the development potential of new agricultural business entities.

Criterion layer	Index layer	Index description
Development endurance	Education level	Primary school and below = 1, junior high school = 2, high school = 3, college and above = 4
	Average age of employed labor force	Years
	Sex structure	The proportion of male labor in the total labor
	Vocational skill satisfaction	Dissatisfied = 1, basically meet = 2, satisfy = 3
	Agricultural machinery and car ownership	Species number
	Scale of business	Hectares
	Frequency of using computer	Almost no use = 1, less use = 2, frequent use = 3
	Introduction of new equipment	Equipment updated within 3 years. No = 0, yes = 1
	Adopt new technologies	Application of breeding, agricultural machinery, greenhouse, irrigation, planting, plastic film mulching, professional fertilization, and other advanced agricultural technology. No = 0, yes = 1
	Introduction of new varieties	The introduction of 'high quality', 'disease (insect)', and other new varieties. No = 0, yes = 1
Economic performance	Asset–liability ratio	Total liabilities/total assets * 100%
	Assets turnover	Total turnover/total assets * 100%
	Sales net profit ratio	Net profit/sales * 100%
	Assets reward ratio	Net profit/total assets * 100%
	Credit demand	None = 0, yes = 1
Social performance	Cultivation of New Agricultural Format	Development of ecology agriculture, circulation agriculture, seed agriculture, leisure agriculture or exhibition agriculture. No = 0, yes = 1
	Standardized production	No = 0, yes = 1
	Public goods supply	Investment in the Supply of Rural Public Goods (ten thousand yuan)
	Mean of driving farmers	Households
	Employment absorption index	Number of labor employed/number of labor released by land transfer * 100%
Ecological performance	Total input of fertilizer, pesticide, and agricultural film per unit area	Ten thousand yuan/hm^2
	Get pollution-free, green or organic agricultural products certification	No = 0, yes = 1
	Water-saving irrigation rate	Water saving irrigation area/land management area * 100%
	Waste recycling and treatment	None = 0, yes = 1
Development prospect	R&D investment	None = 0, yes = 1
	Have a registered trademark or own brand	No = 0, yes = 1
	Financing plans	Plan to expand sales channels and increase marketing, introduce advanced equipment to expand the scale of operation or increase the scale of financing, etc. None = 0, yes = 1
	Policy support expectation	Expect the government to strengthen industrial policy, finance, political incentives, and other aspects of support. No expectation = 0, expecting one aspect to be strengthened = 1, expecting two aspects to be strengthened = 2, expecting all aspects to be strengthened = 3

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and the contribution to the increase of farmers' income (Ruan et al., 2017, 2022), which is embodied in the radiation and driving effect on agriculture, rural areas, and farmers. The ecological performance dimension includes the ability to achieve green sustainable development and environmental awareness. The cultivation of new agricultural business entities has improved the quality of agricultural products and effectively promoted the development of green agriculture in China (Liu and Wu, 2022). Indicators are chosen to assess the development potential of new agricultural business entities based on their innovation consciousness, brand building, development confidence, and governmental support. This ensures an increase in agricultural output efficiency.

2.2.3 Descriptive statistics

From Table 2, it can be seen that in terms of development sustainability, the education level of the labor force employed by the new business entities in the study area is generally low, the age is older, and the labor force is mainly female. Only a small part of the employed labor force has related vocational skills, and most of the new business entities may be restricted by terrain factors that limit the use of agricultural machinery and other equipment. Therefore, new business entities are constrained by the labor force, and the scale of operation is not large. Due to the differences in resource endowments of different types of new business entities, the scale of operation varies greatly among the entities. The maximum operating scale was 866.667 hm2, and the minimum operating scale was 0.025 hm2. The introduction of new equipment, adoption of new technologies, and introduction of new varieties of the number were also very small, so the development of new business entities in the study area continued to be weak. In terms of economic performance, the average asset–liability ratio of the new business entities was low, the capital turnover rate and sales net profit were high, and the return on investment was high. Therefore, the economic performance of the new business entities in the study area was good. In terms of social performance, although few new business entities in the study area had achieved the cultivation of new agricultural businesses and standardized production, they had made outstanding contributions to promoting the employment of farmers in the surrounding areas. In terms of ecological performance, the new business entities in the study area seldom used pesticides, fertilizers, and agricultural films and performed well in waste recycling and treatment.

However, the majority of the agricultural products did not possess a certification indicating that they are pollution-free and environmentally friendly organic agricultural products. Regarding development possibilities, the majority of new business entities in the research area had their own registered trademarks and logos and also received substantial policy backing, which is indicative of significant growth potential.

2.3 Methods

The projection pursuit model is a novel statistical method to deal with multi-factor, high-dimension, and non-linear data. This method is used to project high-dimension data onto a low-dimension space and analyzes the characteristics of high-dimension data structure in a low-dimension space, fully reflecting the characteristics of the data, so that the evaluation results are not disturbed and truly reflect the evaluation results (Liu et al., 2022). It has been widely used in the evaluation of water resources carrying capacity (Wei et al., 2019), urban ecology (Liu et al., 2020; Liu and Li, 2022), and the ecological compensation effect (Meng et al., 2019). The specific calculation steps are described below:

2.4 Normalization of original data

Setting the sample set to $\left\{x^*(i,j)|i=1\sim n, j=1\sim p\right\}$, among them, the $x^*(i,j)$ means raw data for the jth evaluation index in the ith new business entity. n is the number of new business entities, and p is the number of evaluation indicators.

Due to the difference in the dimensions of some evaluation indicators, the range of changes in the original values of each evaluation index is not the same, and there is a lack of comparability, so it is necessary to standardize treatment (Wei et al., 2019). The original data of the evaluation index can be standardized by the range method:

$$x(i,j)=\left[x^*(i,j)-x_{\min}(j)\right]/\left[x_{\max}(j)-x_{\min}(j)\right] \quad (1)$$

$$x(i,j)=\left[x_{\max}(j)-x^*(i,j)\right]/\left[x_{\max}(j)-x_{\min}(j)\right] \quad (2)$$

In the Equations (1, 2), $x_{\max}(j)$ and $x_{\min}(j)$ are the maximum and minimum values of the raw data of the jth evaluation index. $x(i,j)$ is a standardized value for evaluation indicators. $x(i,j)$ is the normalized value (in the range of 0 to 1).

2.5 Establishment of the projection objective function

In the Equation (3), $a=\{a(1),a(2),\ldots,a(p)\}$ is the unit projection direction vector, and the one-dimensional projection value (Liu and Li, 2022) of sample i in this direction is:

$$Z(i)=\sum_{j=1}^{p}a(j)x(i,j)\,(i=1\sim n) \quad (3)$$

Then, $Z(i)$ is classified based on a one-dimensional scatter diagram, which requires local projection points to remain as dense as possible, which would be better to gather into one cluster; and projection points between clusters should spread out as far as possible. So objective function can be defined as the product between the distance and density of the category, that is Equation (4):

$$Q(a)=S_zD_z \quad (4)$$

where S_z and D_z are the standard deviation and local density of the projected value $Z(i)$, respectively, namely:

$$S_z=\sqrt{\sum_{i=1}^{n}\left(Z(i)-E(z)\right)^2/(n-1)} \quad (5)$$

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TABLE 2 Descriptive statistics of input–output indicators and other factors.

Criterion layer	Index layer	*N*	Minimum value	Maximum value	Mean value	Standard deviation
Development endurance	Education level	408	0	5	2.51	0.99
	Average age of employed labor force	408	30	77	54.75	6.93
	Sex structure	408	0	5	0.66	0.79
	Vocational skill satisfaction	408	1	3	2.02	0.79
	Agricultural machinery and car ownership	408	0	12	2.09	2.02
	Scale of business	408	0.025	866.66	19.01	56.65
	Frequency of using computer	408	1	3	1.32	0.63
	Introduction of new equipment	408	0	1	0.55	0.49
	Adopt new technologies	408	0	1	0.41	0.49
	Introduction of new varieties	408	0	1	0.18	0.38
Economic performance	Asset–liability ratio	408	0	1	0.11	0.21
	Assets turnover	408	0.1	62	1.42	3.86
	Sales net profit ratio	408	0.1	0.65	0.28	0.07
	Assets reward ratio	408	0.0125	18.60	0.42	1.27
	Credit demand	408	0	1	0.23	0.42
Social performance	Cultivation of New Agricultural Format	408	0	1	0.16	0.37
	Standardized production	408	0	1	0.19	0.39
	Public goods supply	408	0	600	7.04	46.75
	Mean of driving farmers	408	0	200	6.29	26.25
	Employment absorption index	408	0	5.55	0.13	0.36
Ecological performance	Total input of fertilizer, pesticide. and agricultural film per unit area	408	0	12.85	0.85	1.17
	Get pollution-free, green or organic agricultural products certification	408	0	1	0.11	0.31
	Water-saving irrigation rate	408	0	1	0.09	0.2
	Waste recycling and treatment	408	0	1	0.54	0.49
Development prospect	R&D investment	408	0	1	0.12	0.33
	Have a registered trademark or own brand	408	0	1	0.20	0.40
	Financing plans	408	0	1	0.37	0.48
	Policy support expectation	408	0	3	1.75	1.02

$$D_z = \sum_{i=1}^{n}\sum_{j=1}^{p}\left(R - r\left(i,j\right)\right)u\left(R - r\left(i,j\right)\right) \tag{6}$$

In the Equations (5, 6), $E\left(z\right)$ is the sequence $\left\{Z\left(i\right)\middle|i = 1 \sim n\right\}$ average. R is the window radius of local density. The distance $r\left(i,j\right) = \left|Z\left(i\right) - Z\left(j\right)\right|$, $u\left(R - r\left(i,j\right)\right)$ is the unit step. This step is assumed to be 1 when $R \geq r\left(i,j\right)$; otherwise, it is assumed to be 0.

2.6 Optimization of projection direction

After the sample set is determined, the change of projection direction vector a determines the change of projection objective function $Q\left(a\right)$. Different data structure features are represented by different projection direction vectors. The projection direction vector that can best reflect some structural features of high-dimensional data is the best projection direction vector. From Equations (7, 8), by setting constraint conditions, the maximized projection objective function is solved, and the direction vector of the nearest projection is calculated (Liu and Li, 2022), namely:

Objective function maximization:

$$maxQ\left(a\right) = S_z D_z \tag{7}$$

Constraint condition:

$$\sum_{j=1}^{p} a^2\left(j\right) = 1 \tag{8}$$

This is $\left\{a_j = |j = 1 \sim p\right\}$ as optimization variables, a complex non-linear optimization problem, and it is difficult to use conventional optimization methods. The accelerated genetic algorithm is adopted to solve the optimal problem in the paper.

2.7 Sorting

By acquiring the optimal projection direction vector, one can calculate the projection value of each sample point by multiplying the standardized value of the relevant evaluation index with the optimal projection direction vector and summing them together. According to the size of the sample projection value, the sample can be sorted. According to the optimal projection direction vector, which is the weight of the evaluation index, the influence degree of each evaluation index on the subsystem and system can be determined.

3 Results

3.1 Influencing factors of the development potential of new agricultural business entities

The direction vector of each index for the evaluation of the development potential of new agricultural business entities is shown in Figure 2. It can be seen that the adoption of new technologies has the greatest impact on the development potential of new agricultural business entities, with a direction vector of 0.8391. Therefore, the adoption of advanced agricultural production technology by new agricultural management entities greatly influences their development potential. In addition, introducing new varieties had a direction vector of 0.3771. Of note, it is crucial for new agricultural business entities to introduce new varieties in agricultural planting and production. New varieties may bring better benefits and lower costs. The smallest projection direction vector was the financing plan at 0.0015. The financing plan had little impact on the development potential of the new agricultural business entities in the study area. Most of the new agricultural business entities in the study area had sufficient funds of their own reducing their use of the financing plan, with some of the entities also receiving policy subsidies from the local government. From the perspective of the development potential direction vector of different dimensions (Figure 3), the largest development potential direction vector was the adoption of new technologies and the introduction of new varieties, and the smallest was the scale of land management; in terms of economic performance, the largest direction vector was sales net profit and return on assets, and the smallest was credit demand; the largest direction vector of social performance was the implementation of standardized production, and the smallest was the employment absorption index; in terms of ecological performance, the largest direction vector was the water-saving irrigation rate, and the smallest was the total input of chemical fertilizer, agriculture, and agricultural film per unit area. In terms of development prospects, the largest direction vector was research and development R&D investment, and the smallest was the financing plan.

3.2 Evaluation of the development potential of new agricultural business entities

Based on the constructed evaluation system for the development potential of new business entities, the typical new business entities in the study area were taken as the measurement objects, with a sample dimension of 408 and index number of 28. The projection pursuit comprehensive evaluation method in DPS statistical software is used for data processing and analysis. After optimization, the best projection direction was obtained, and then, the comprehensive value of the development potential of different types of new business entities (Figure 4) was calculated. Compared with different types of new business entities, the average projection value of agricultural enterprises was the largest at 1.0051, followed by farmers' cooperatives at 0.8135 and, specifically, 0.6513 for large farmers with a minimum number of family farms of 0.5972. The comprehensive projection values of different new business entities varied by entity type: agricultural enterprises (0.0988–2.3812), farmers' cooperatives (0.1082–2.2303), large farmers (0.0976–1.7309), and family farms (0.0993–2.0563). The highest comprehensive projection value was for agricultural enterprises, while the lowest was for large farmers. Considering different dimensions, the average development endurance of agricultural enterprises was the highest, with an average projection value of 0.7571, followed by farmers' cooperatives at 0.6127. The average projection values of both large and family farms were less than 0.5, and the minimum projection value of family farms was 0.4116. Two new types of business entities, namely, agricultural enterprises and farmers' cooperatives, were larger in scale and focused more on the use of information technology, which resulted in advantages in terms of development endurance. There was little difference in the projection value of the economic performance dimension, which was less than 0.04 (between 0.033 and 0.037). It also shows the characteristics of agricultural enterprises > farmers' cooperatives > large farmers > family farms. The average projection value of social performance of agricultural enterprises was the highest, with outstanding ability in radiating and driving agriculture, rural areas, and farmers. There were minimal differences in the projection value of the other three types of new business entities, followed by family farms, farmers' cooperatives, and large farmers. The maximum average projection value of the ecological performance of agricultural enterprises was 0.0786, followed by family farms at 0.0726. The projection values of farmers' cooperatives and large farmers were relatively small, at 0.0670 and 0.0654, respectively. The results indicated that the large farmers and farmers' cooperatives should strengthen the protection of the ecological environment and enhance the awareness of environmental protection.

By using the natural discontinuity point method, the comprehensive projection value of the new business entity was divided into three levels: low, medium, and high, to characterize the development potential of the new business entity. Low-potential new business entities were between 0.0976 and 0.6683 accounting for 58.33% of all new business entities. Of these, agricultural enterprises accounted for 10.29%, farmers' cooperatives for 14.95%, family farms for 26.72%, and large farmers for 6.37%. The medium-potential new business entities ranged from 0.6683 to 1.4745 accounting for 22.06% of all new business entities. Of these, agricultural enterprises accounted for 6.86%, farmers' cooperatives for 7.11%, family farms for 7.35%, and large farmers for 0.74%. High-potential new business entities ranged from 1.4745 to 2.3812 accounting for 19.61% of all new business entities, including 7.60% of agricultural enterprises, 5.64% of farmers' cooperatives, 4.66% of family farms, and 1.72% of large farmers. Regarding the category of new business entities (Figure 5), all types of new business entities were mainly low potential. Of these, low-potential agricultural enterprises accounted for 41.58% of all

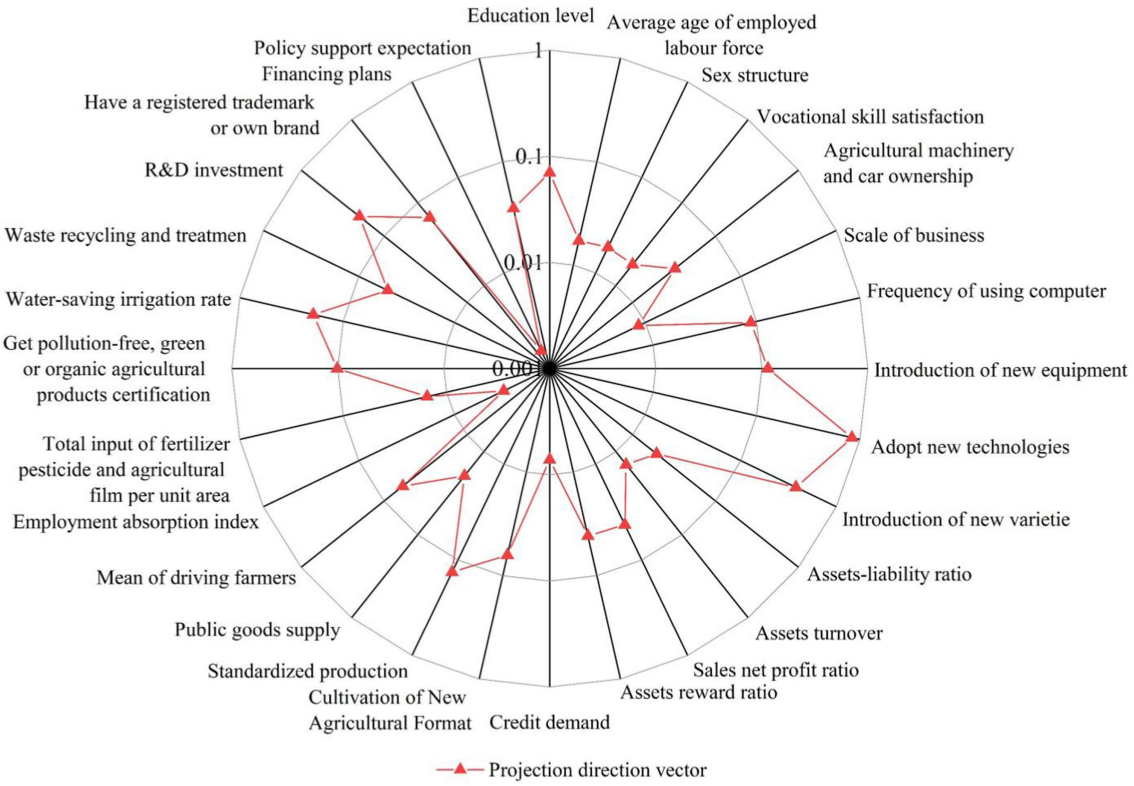

FIGURE 2
Direction vector of indexes of the development potential indexes of new agricultural business entities entities.

agricultural enterprises, medium- and high-potential agricultural enterprises accounted for more than 50%, and high-potential agricultural enterprises accounted for slightly higher than medium-potential agricultural enterprises, 30.69 and 27.72%, respectively, indicating that the development momentum of agricultural enterprises was good. Low-potential farmers' cooperatives accounted for 53.98% of all farmers' cooperatives, followed by medium potential (25.66%) and high potential (20.35%). High-potential family farms represented the lowest percentage of all high-potential new business entities (12.03%), indicating that the vast majority of family farms had insufficient development momentum, and the cultivation of high-quality family farms should be strengthened. The proportion of low-potential large farmers in all low-potential new business entities was the highest at 72.22%. The medium-potential large farmers constituted the lowest of all medium-potential new business entities at 8.33%, indicating that most large farmers had a poor development base and should start from medium- and low-potential large farmers to optimize the use of existing resources and enhance the development level.

From the perspective of industrial type (Figure 6), the new business entities included fruits and vegetables, peppers, comprehensive, flowers and trees, grain and oil, and characteristic industries. Of these, the comprehensive new business entities had the greatest development potential, with an average projection value of 1.1156, and the characteristic industries had the lowest development potential, with an average projection value of 0.4499. However, the development potential of different industries of four types of new business entities was significantly different. The development potential of fruits and vegetables in agricultural enterprises was greater than that of the other five industries, with an average projection value of 1.1441. Characteristic agricultural enterprises had the lowest development potential, with an average projection value of 0.3314. The comprehensive type of farmers' cooperatives had the largest development potential with an average projection value of 1.3430. The flowers and trees type of farmers' cooperatives had the lowest development potential at 0.3548. The development potential of comprehensive family farms was also greater than that of other industries. The average projection value was 1.0543, and the average projection value of characteristic industries was the lowest at 0.1712. The large farmer with the largest average projection value was the grain and oil industry, while the lowest was the comprehensive large farmer, however, there was only one comprehensive large farmer, so the data was not representative, and the value for peppers was 0.4208, which was only higher than the comprehensive. In essence, projection value differences for different industries of various new business entities according to various dimensions explain the differences observed in the development potential of different industries of the four types of new business entities (Figure 7). In agricultural enterprises, the average projection values of fruits and vegetables according to the three dimensions of development endurance, social performance, and ecological performance were the highest at 0.8675, 0.0633, and 0.0957, respectively. Fruit and vegetable planting had a good industrial foundation and required considerable labor for a long period of time. According to the ecological aspect, it usually pays attention to controlling the application of pesticide fertilizer and increases the area of regional greening during the planting process.

FIGURE 3
Direction vectors of development potential indexes of new business entities under different dimensions of **(A)** development endurance, **(B)** economic performance, **(C)** social performance, **(D)** ecological performance, and **(E)** development prospect.

Therefore, development endurance, social performance, and ecological performance were better than those in other industries. The average projection values of characteristic agricultural enterprises in the three dimensions were the lowest. Cultivation and the development of characteristic agricultural enterprises in future should focus on improving development endurance, social performance, and ecological performance. According to the two dimensions of economic performance and development prospects, the average projection value of characteristic agricultural enterprises was higher than that of agricultural enterprises in other industries, at

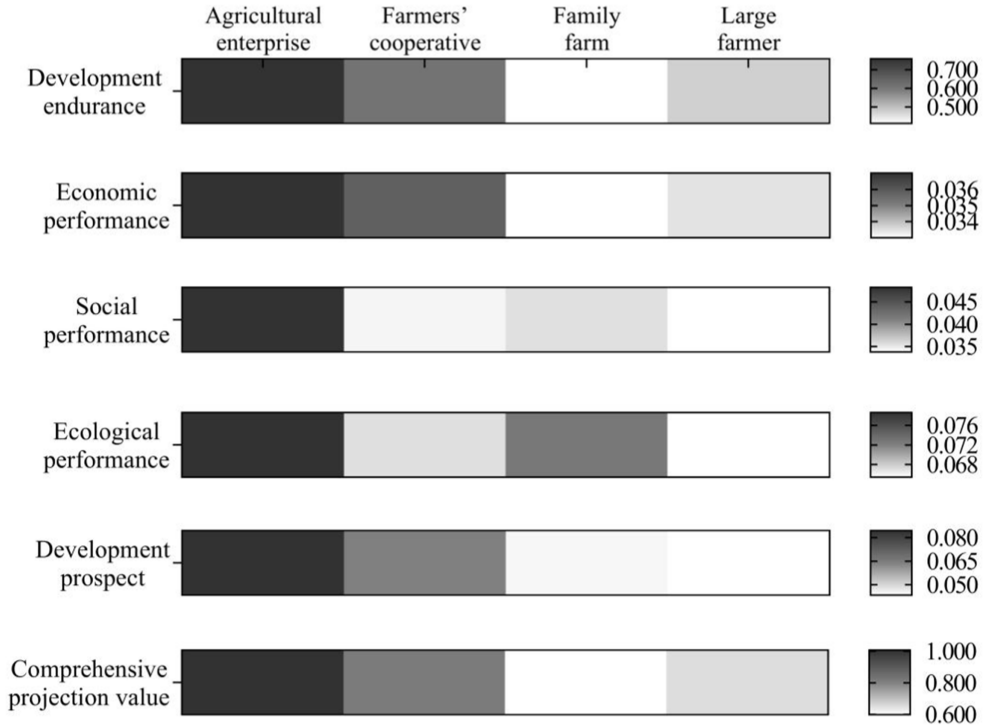

FIGURE 4
Different dimensions and comprehensive projection values of different new agricultural business entities.

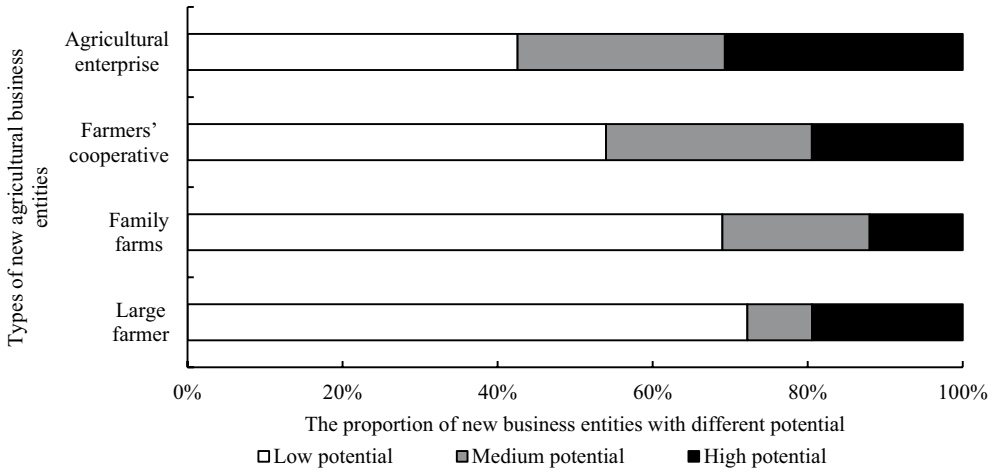

FIGURE 5
Quantitative structure of various types of new agricultural business entities with different potential.

0.0520 and 0.2217, respectively, indicating that the development of characteristic industries can achieve considerable economic income. Compared with other industries, its innovation consciousness is more prominent. Grain and oil agricultural enterprises were not performing well in these two aspects. As a traditional industry, grain and oil should actively take innovative measures to improve production efficiency. In farmers' cooperatives, the development endurance and development prospects of comprehensive industries were significantly better than those in other industries. The average projection value of development endurance was greater than 1, and the average projection value of development prospects was greater than 0.1, while flowers and trees had the lowest performance in both dimensions, only 0.2304 and 0.0195. Comprehensive farmers' cooperatives developed three or more industries, underscoring good basic conditions and a strong sense of innovation. According to the economic performance dimension, the average projection value of each industry was comparable, between 0.0336 and 0.0382. The average projection values of the two dimensions of social performance and ecological performance were the highest in grain and oil, 0.0678 and 0.0885, respectively. Among the family farms, the average

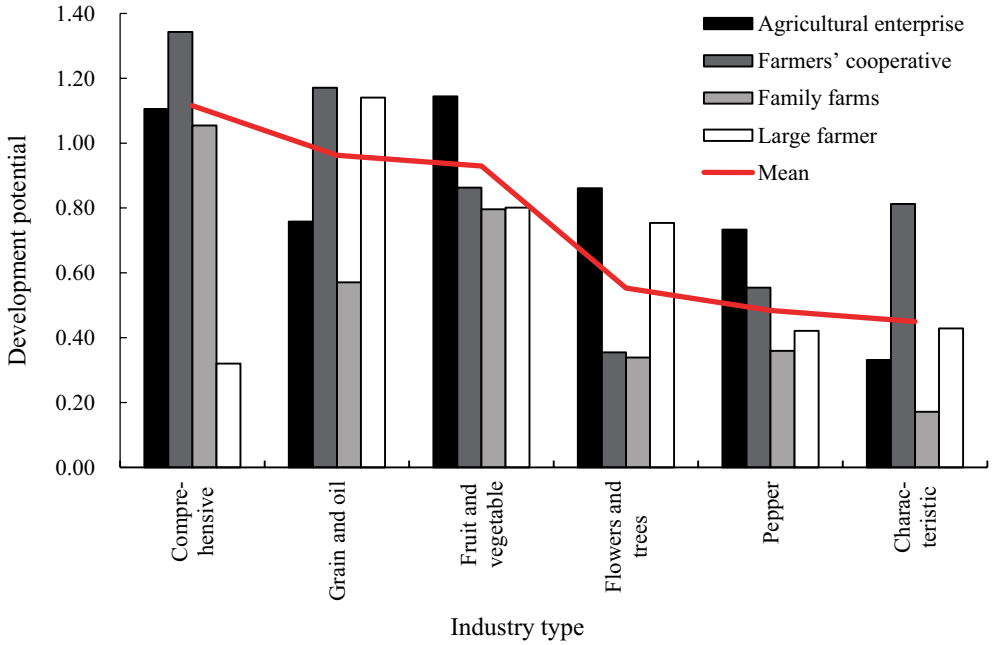

FIGURE 6
Development potential of different types of new agricultural business entities across various industries.

projection values of comprehensive family farms in the four dimensions of development endurance, social performance, ecological performance, and development prospect were significantly greater than those of the other five industries, and the economic performance dimension was the highest in the characteristic, which is 0.0368. The two dimensions of development endurance and ecological performance were the lowest average projection values of the characteristic class, which were 0.0663 and 0.0235, respectively. During the inquiry, it was discovered that the distinctive family farm had a very short establishment time and little investment in fundamental circumstances, resulting in a weak development endurance. In the two dimensions of economic performance and social performance, the average projection value of grain and oil was the lowest, which was 0.0312 and 0.0003, respectively. The grain and oil industry operated by families was usually small in scale, with low economic benefit, and the drive to agriculture, rural areas, and farmers was not strong. In the development prospect dimension, the average projection value of flowers and trees was the lowest at 0.0224. In the development process, it is important to focus on the cultivation of innovation consciousness. Among the large farmers, the average projection values of grain and oil were the highest in the two dimensions of development endurance and ecological performance, at 0.8751 and 0.1300, respectively. The highest average projection value of economic performance and development prospects was the characteristic, and the highest average projection value of social performance was the fruit and vegetable. Fruits and vegetables usually require considerable labor in the picking process, so these perform better in the social performance dimension. The average projection values of the three dimensions of development endurance, social performance, and development prospects were the lowest in the characteristic. The lowest economic performance was observed for grain and oil, and the ecological performance of large farmers was the lowest. The reason for this finding may be that the cultivation of flowers and trees requires a large amount of pesticides and fertilizers. In terms of quantity, high-potential agricultural enterprises, high-potential family farms, and high-potential large farmers produced the largest number of fruits and vegetables, accounting for 18.81, 5.70, and 11.11%, respectively, of the three types of new business entities. However, the highest number of high-potential farmers' cooperatives was found in the grain and oil industry accounting for 7.08% of the total number of farmers' cooperatives.

3.3 Spatial pattern of development potential of new agricultural business entities

Kernel density estimation is used to explore the high-density areas of various types of new business entities with different development potential. As can be seen from Figure 8, the high-density areas of new business entities with three types of potential are located in Ciyun Town and Shimen Town, and the kernel density of new business entities with low potential is significantly higher than that of the other two types. Furthermore, the kernel density of new business entities with medium potential was the lowest. Low-potential new business entities formed a major agglomeration center in the north of Ciyun Town and a secondary agglomeration center in the south of Ciyun Town. The spatial distribution of new business entities with medium potential showed two main clustering centers, located in Shimen Town and Ciyun Town, respectively. High-potential new business entities showed two main agglomeration centers in terms of spatial distribution. The small agglomeration center was located in Shimen Town, and the large agglomeration center was distributed in Ciyun Town.

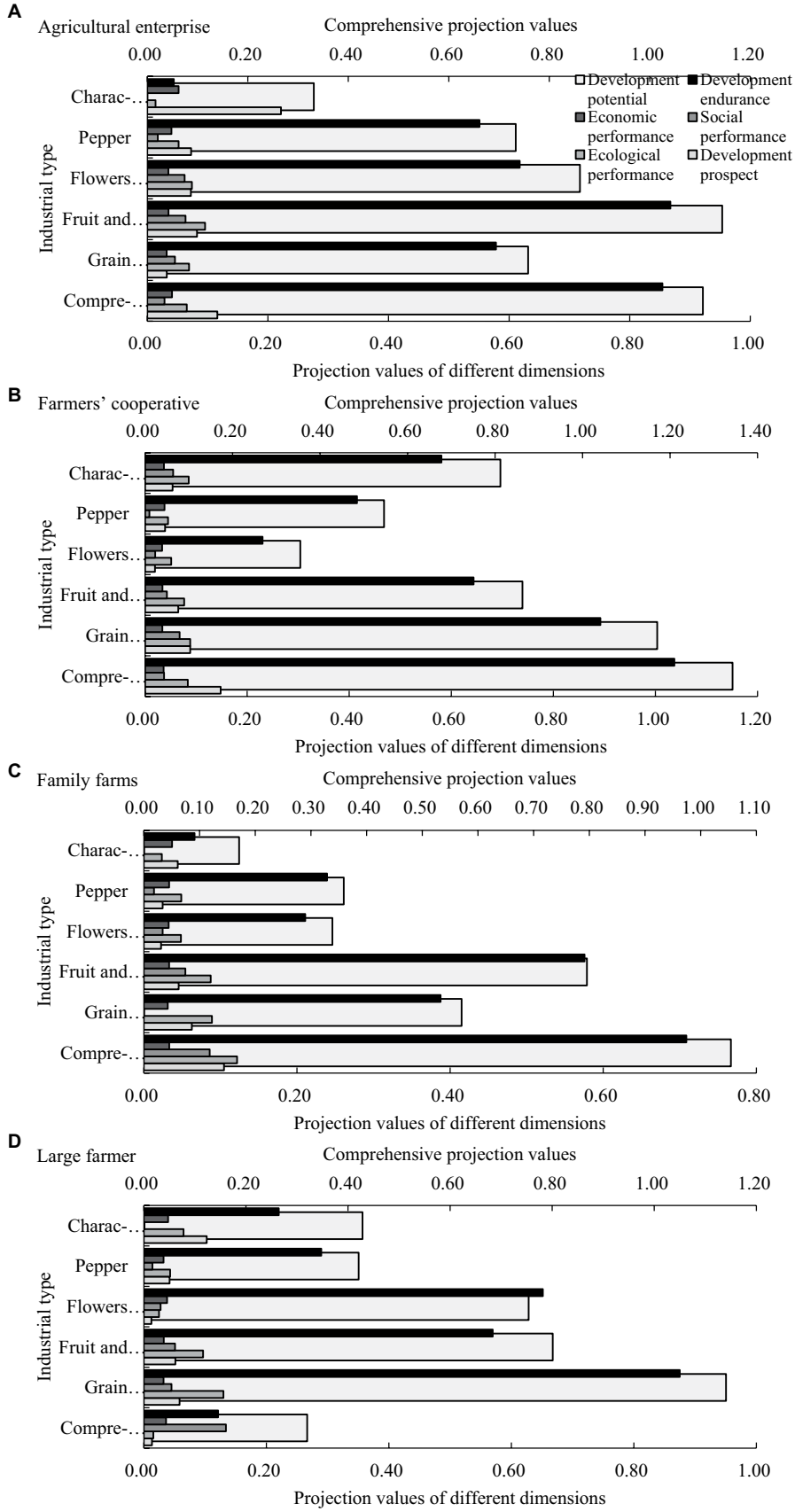

FIGURE 7
Projection values of different dimensions and composite for **(A)** Agricultural enterprise, **(B)** Farmers' cooperative, **(C)** Family farms, and **(D)** Large farmer in different industries.

From the perspective of the new business entity category, among the three types of agricultural enterprises, the high-potential kernel density value was slightly higher than the low potential, and the medium-potential agricultural enterprise kernel density value was the lowest. In terms of spatial distribution, high- and medium-potential agricultural enterprises were similar to high- and medium-potential new business entities. High-potential agricultural enterprises formed two single-core agglomeration centers in Shimen Town and Ciyun Town. The agglomeration center of medium-potential agricultural enterprises was mainly located in the north of the study area, and the three main agglomeration centers were distributed in Shimen Town, Longhua Town, and Ciyun Town. Low-potential agricultural enterprises were different from all low-potential new business entities, forming three agglomeration centers in the southwest of the study area, located in Shimen Town, Baisha Town, and Yongxing Town. The kernel density values of the three types of farmers' cooperatives were not significantly different, although the spatial distribution was significantly different. The high-density area of low-potential farmers' cooperatives had a wider distribution range than that of all low-potential new business entities, mainly located in the northern part of the study area. It forms a large and small dual-core agglomeration center in Shimen Town and was distributed in high-density areas of Longhua Town, Ciyun Town, and Xianfeng Town, showing four main agglomeration centers. The distribution of high-density areas of medium-potential farmer cooperatives was slightly different from that of medium-potential new business entities, mainly distributed in the northern part of the study area, forming a major agglomeration center in Ciyun Town and forming a secondary agglomeration center in Xianfeng Town. The high-density area of high-potential farmers 'cooperatives moved to the mid-west, presenting a single-core gathering center in the north of Yongxing Town and the middle of Baisha Town. There were considerable differences in kernel density values of the three types of family farms, with low-potential family farms being the highest, followed by medium-potential family farms, and high-potential family farms being the lowest. However, there was little difference in the distribution

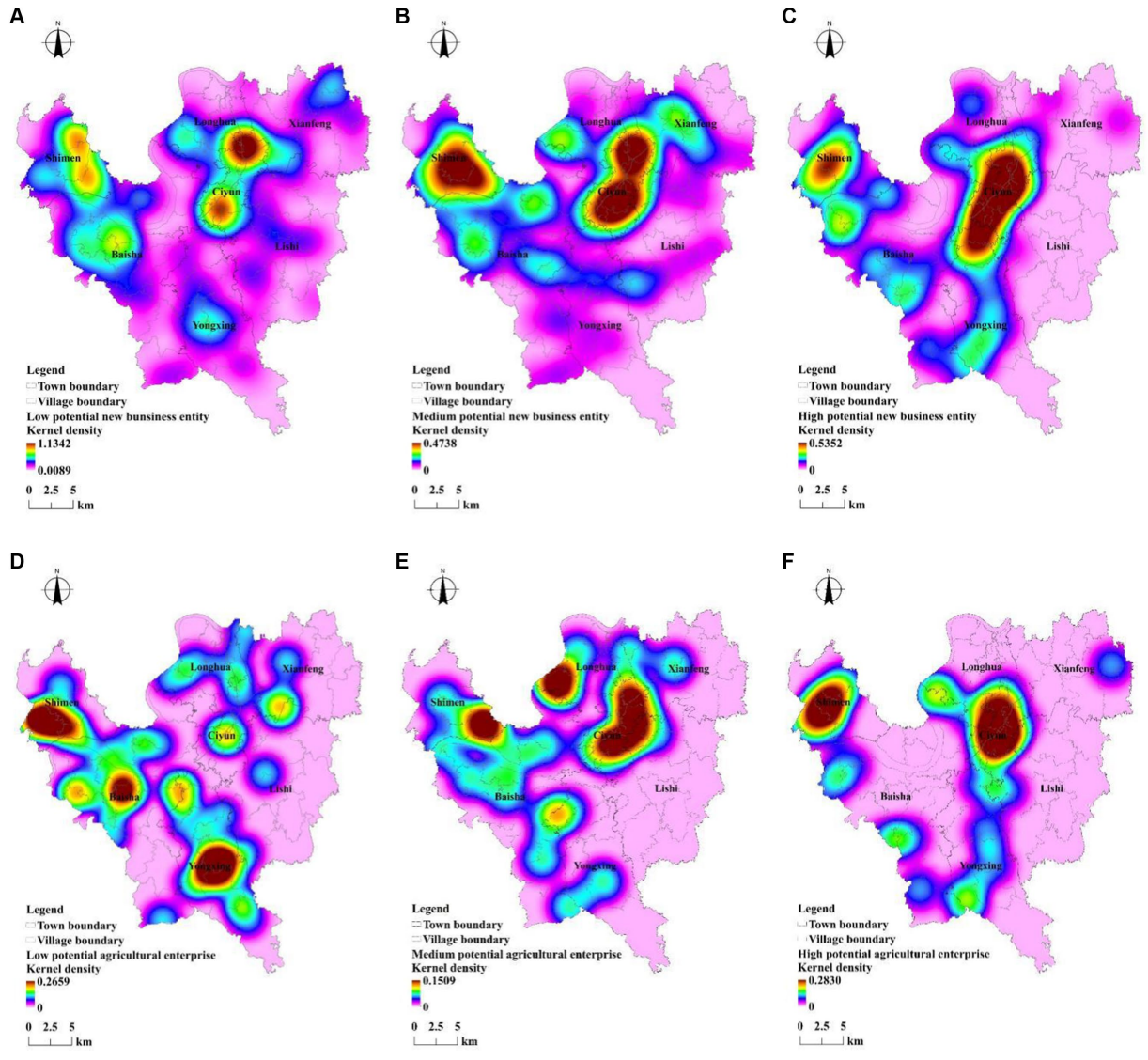

FIGURE 8 (Continued)

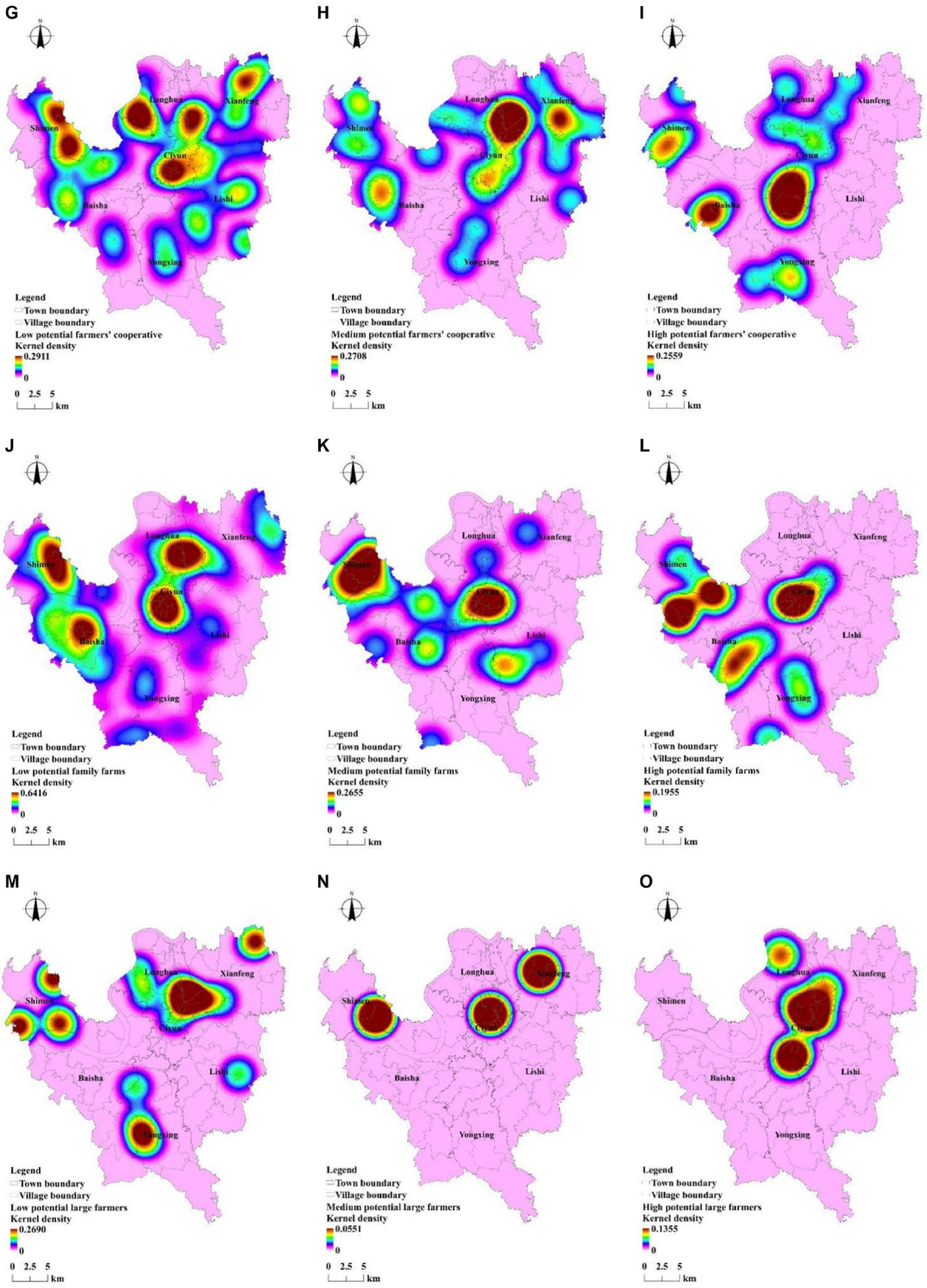

FIGURE 8
Estimation of kernel density of various types of new agricultural business entities with different potential. **(A)** Kernel density of low potential new business entity; **(B)** Kernel density of medium potential new business entity; **(C)** Kernel density of high potential new business entity; **(D)** Kernel density of low potential agricultural enterprise; **(E)** Kernel density of medium potential agricultural enterprise; **(F)** Kernel density of high potential agricultural enterprise; **(G)** Kernel density of low potential farmers' cooperative; **(H)** Kernel density of medium potential farmers' cooperative; **(I)** Kernel density of high potential farmers' cooperative; **(J)** Kernel density of low potential family farms; **(K)** Kernel density of medium potential family farms; **(L)** Kernel density of high potential family farms; **(M)** Kernel density of low potential large farmers; **(N)** Kernel density of medium potential large farmers; **(O)** Kernel density of high potential large farmers.

of high-density areas in space, with most areas distributed in the central and western regions of the study area. The high-density areas of low-potential family farms were more widely distributed than low-potential new business entities, forming four agglomeration centers in Shimen Town, Baisha Town, and Ciyun Town, respectively. The two main agglomeration centers of medium-potential family farms were located in Shimen Town and Ciyun Town, which was consistent with the distribution of the agglomeration centers of medium-potential new business entities. The high-potential family farms had two main agglomeration centers and a secondary agglomeration center. The main agglomeration centers were distributed in the north of Baisha Town and the middle of Ciyun Town, respectively. The secondary agglomeration center was located in the middle of Baisha Town. This shows that Baisha Town and Ciyun Town have a good foundation for the development of family farms and are more suitable for cultivating high-potential family farms. Due to the small number of large farmers, their kernel density values were small with significant high-density areas. On the basis of the two high-density areas of Shimen Town and Ciyun Town presented by the new business entities with medium potential, there were also agglomeration centers in Xianfeng Town. The medium-potential large farmers show three main agglomeration centers, which were located in Shimen Town, Ciyun Town, and Xianfeng Town. The high-potential large farmers formed a large and small dual-core agglomeration center in Ciyun Town and a secondary agglomeration center in Longhua Town.

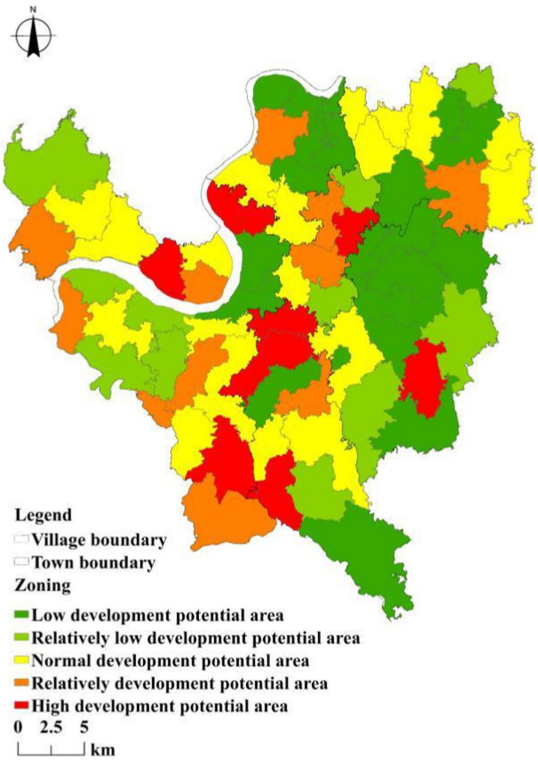

FIGURE 9
Spatial distribution of development potential types of new agricultural business entities in villages.

3.4 The development potential of new agricultural management entities in villages

Considering the village as the unit, the average value of each dimension and comprehensive projection value of the new business entities in 68 sample villages in the study area were taken as the average value of each dimension and comprehensive projection value of the sample village. Using the natural discontinuity point method, the comprehensive projection values of each village were divided into five levels: low, relatively low, normal, relatively high, and high, to characterize the development potential of the new business entities in each village (Figure 9). The comprehensive projection value of the low development potential area was between 0 and 0.296701. There were 20 sample villages in this area, accounting for 29.41% of all villages. The comprehensive projection value of the relatively low development potential area was between 0.296702 and 0.583359, a total of 11 sample villages, accounting for 16.18% of all villages. The comprehensive projection value of the normal development potential area was between 0.583360 and 0.842610, a total of 19 sample villages, accounting for 27.94% of all villages. The comprehensive projection value of the relatively high development potential area was between 0.842611 and 1.150622, a total of 11 sample villages, accounting for 16.18% of all villages. The comprehensive projection value of the high development potential area was between 1.150623 and 1.517502. The number of sample villages in this area was only 7, accounting for 10.29% of all villages. In the low development potential area, Longhua Town and Lishi Town had a large number of villages, with 6 and 7 villages, respectively, both exceeding 60% of the total number of each town. There were three villages in Xianfeng Town accounting for 30% of the total number of villages in the town. Yongxing Town and Baisha Town included 2 villages each, accounting for 22.22 and 10.53% of the total number of villages in each town. In the relatively low development potential area, there were 2 villages in Ciyun Town accounting for 33.33% of the total number of villages in the town, 1 village in Xianfeng Town accounting for 10% of the total number of villages in the town, 2 villages in Lishi Town accounting for 18.18% of the total number of villages in the town, 1 village in Yongxing Town accounting for 11.11% of the total number of villages in the town, 4 villages in Baisha Town accounting for 21.05% of the total number of villages in the town, and 1 village in Shimen Town accounting for 25% of the total number of villages in the town. In the normal development potential area, Baisha Town had the greatest number of villages with 6 villages accounting for more than 30% of the total number of villages in the town. There were 5 villages in Xianfeng Town accounting for 50% of the total number of villages in the town. Longhua Town, Yongxing Town, and Shimen Town included 2 villages accounting for 22.22, 22.22, and 50% of the total number of villages in each town, respectively. Ciyun Town and Lishi Town had 1 village accounting for 16.67 and 9.09% of the total number of villages in each town. In the relatively high development potential area, Baisha Town had the largest number of villages, with 5 villages accounting for 26.32% of the total number of villages in the town, followed by Ciyun Town with 2 villages and accounting for 33.33% of the total number of villages in the town. Longhua Town, Yongxing Town, and Shimen Town included 1 village accounting for 11.11, 11.11, and 25% of the total number of villages in each town. In the high development potential area, Ciyun Town had 1 village accounting for 16.67% of the total number of villages in the town, Lishi Town had 1 village accounting for 9.09% of the total number of villages in the town, Yongxing Town had 3 villages

accounting for 33.33% of the total number of villages in the town, and Baisha Town had 2 villages accounting for 10.53% of the total number of villages in the town. From the town scale, Baisha Town, Xianfeng Town, and Shimen Town were mainly normal development potential areas, at a medium level for the five dimensions of development endurance, economic performance, social performance, ecological performance, and development prospects. Accordingly, the development advantages were more significant. Lishi Town and Longhua Town were dominated by low development potential, at a low level for all dimensions. Furthermore, the development of industry in some villages was also one of the main reasons for the low development potential of their new business entities. Yongxing Town was dominated by high development potential areas, and most villages reached the upper middle level across all dimensions. Ciyun Town was dominated by relatively high development potential areas. The town is located in the core area of Jiangjin Modern Agricultural Park, and the construction of new agricultural management entities commenced earlier.

4 Discussion

Analyzing the differences in resources among different agricultural entities can provide valuable insights into resource utilization strategies. We start from the perspective of the scale of farmers, divided into terrain area, industry type, and business entities type, comparing the differences of different new main bodies in human resources, land resources, social resources, information resources, financial capital, and material capital, analyzing how each of them makes use of their advantages to integrate resources (Zhan, 2023), and how they can achieve complementary of advantages with each other, and focusing on the economic performance indicators like debt repayment ability, asset management ability, profitability and financial credit, and radiation-driven ability. The development potential of different new business entities is examined from the perspective of economic performance (solvency, asset management, profitability, and financial credit), radiation-driven capacity, development prospects (green and sustainable development capacity, innovation awareness, and brand building) (da Silva and Gameiro, 2022), profitability, and information technology usage rate. The different new business entities are measured and compared in terms of the indicators of scaling, commodification, hydroponics, facilities, mechanization, technologization, and information technology and in terms of the productivity of land, the productivity of labor, and the utilization rate of resources. It also measures and compares the differences in resource allocation efficiency among different new subjects in terms of land productivity, labor productivity, and resource utilization rate, to reveal the heterogeneity of factors among new business entities.

This study examined multiple indicators based on the five dimensions of development endurance, economic performance, social performance, ecological performance, and development prospect, to comprehensively and systematically determine the development potential of various types of new agricultural business entities. It also explores the benefits and disadvantages of various new business entities throughout the development process. The adoption of new technologies clearly plays a critical role in shaping the potential for growth and success of new business entities. It can enhance efficiency, productivity, and competitiveness in the current dynamic market environment. The utilization of agricultural machinery and new technologies is mostly used in breeding, greenhouse, irrigation, fertilization, and other planting activities in the agricultural production process. Numerous tasks, including farming, sowing, harvesting, and processing, are performed with agricultural machinery. Mechanization in agriculture reflects agricultural modernization. Utilizing innovative agricultural equipment lessens the need for workers, lowering labor costs and increasing output effectiveness. Furthermore, it is advantageous for the processing of agricultural products to lengthen the industrial chain and increase the added value of products, increasing the income of farmers. Only the adoption of new technology has a greater impact on the development potential of new business entities than the introduction of new types of business entities. Similarly, new varieties play a crucial role in enhancing the efficiency of agricultural production by improving the quality of agricultural products (Chen, 2022). New varieties are introduced to aid in the production of high-quality, high-yield agricultural goods and reduce the spread of disease and insect pests. The development potential of new business entities is significantly influenced by investments in R&D. Agriculture-related businesses are becoming a significant player in the creation of innovative agricultural technologies. R&D in new agricultural technology includes R&D in production technology and production equipment. It is important to extend and improve the industrial chain by reducing the cost of agricultural production and increasing the added value of agricultural products after R&D investment (Zhang, 2018). A pivotal step in reducing the waste of agricultural water resources and ensuring food security is the deployment of water-saving irrigation technologies to increase agricultural water usage efficiency (Xu et al., 2021; Yang and Gao, 2021). It is important to achieve sustainable agricultural development and adapt to modern agricultural operations.

The comprehensive projection value of the development potential of different types of new business entities showed that agricultural enterprises were the largest, followed by farmers' cooperatives, large farmers, and family farms. The evaluation results of the five dimensions of development endurance, economic performance, social performance, ecological performance, and development prospects varied according to new business entity type. The largest difference between the four types of new business entities was observed for the development endurance dimension. This reflects the basic conditions of human, material, and information technology of new business entities. The evaluation results showed that the projection value of this dimension was the highest for agricultural enterprises, followed by agricultural cooperatives, large planting and breeding households, and family farms. Family farms have the lowest predicted value, which is consistent with Zhao Ruxue's results under the development potential index (Zhao, 2020). The limited use of information technology is the main reason that the projection value of the development endurance dimension of family farms was lower than that of large-scale farmers. Generally, the scale of operation of family farms is relatively small, with lower use of machinery and information technology than that of larger new business entities. The smallest difference in projection value among the four types of new business entities was observed for the economic performance dimension. This dimension reflects the solvency, asset management ability, profitability and financial credit, and other capabilities of the new business entities. The highest projection value according to the economic performance dimension

remained for agricultural enterprises. This is consistent with the results of the dimension of the benefit improvement effect of new agricultural management entities (Wang et al., 2018) and diverges from the results of the 'New Agricultural Management Entity Development Index Survey Report (Phase V)'. This result may be explained by the fact that the scale of family farms in the study area was smaller than that of the other three types of entities, and capital investment was insufficient, so that higher economic returns could not be achieved. The dimension of social performance reflects the radiation driving ability of new business entities, including the radiation driving of agriculture, rural areas, and farmers. Regarding family farms, social performance was second only to agricultural enterprises, followed by farmers' cooperatives and large farmers. There is a certain difference from the research results on the influence of new agricultural management entities on the operation behavior of small farmers (Ruan et al., 2017). The reason is that in terms of driving farmers, family farms provide temporary jobs that exceed the number of agricultural enterprises and play a positive role in driving farmers to increase their income. The ecological performance dimension reflects the ability to achieve green sustainable development and environmental protection consciousness of new business entities. Resource conservation and environmental protection are important determinants of the long-term sustainable development of new business entities. Therefore, all types of new business entities strengthen the protection of the environment in agricultural production, to achieve green production and efficient utilization of resources. The development prospect dimension reflects the expectation and planning of the new business entities for their future development. The results were consistent with the 'New Agricultural Business Entity Development Index Survey (Phase VI) Report'. The projection value of this dimension was the highest for agricultural enterprises, followed by farmers' cooperatives, family farms, and large farmers. Agricultural enterprises and farmers' cooperatives usually have high expectations for their future development toward standardization, industrialization, and scale.

Based on the development potential evaluation results of 408 new business entities, the development status and future development potential of new business entities in the study area were explored. This is important for improving the development level and enhancing sustainable development ability and provides a basis for the differentiated cultivation of new business entities in the research area. In addition to the villages with industry as the leading industry in the low development potential area, the remaining villages should strengthen the cultivation of new business entities from all aspects. The relatively low-potential areas need to focus on the cultivation of traditional farmers in human capital and enhance their sense of innovation. For example, "Xiao Zhiyuan Pepper Planting Cooperative" in Xiangcao Village, Xianfeng Town, conducted the initial processing of pepper on the basis of single pepper planting, extended the industrial chain, and increased the added value of agricultural products. Normal development potential areas are needed to find economic growth points according to local conditions. For example, 'Fengyue Sensation Stock Cooperative' in Yanba Village, Longhua Town, conducted new agricultural technology training and introduced UAV technology to train local farmers to spray pesticides independently. Lishi Town Daqiao Village "Jiangjunhong Agricultural Professional Cooperative in Jiangjin District of Chongqing" developed characteristic planting crops Toona sinensis, with outstanding economic performance. Relatively high development potential areas should explore new production methods, establish a sound long-term mechanism, and promote the industrial transformation and upgrading of villages while continuing their development. For example, Xiejia Village, Yongxing Town, "Yongxiang Family Farm, Jiangjin District, Chongqing" broadened their sales channels through online media. High development potential areas are more prominent across all dimensions. They can rely on existing conditions to extend the industrial chain, increase current industrial advantages, and achieve industrial transformation and upgrading. This process is not limited to the primary production of agricultural products but includes deep processing of agricultural products, increases the added value of agricultural products, and drives farmers to increase their income. Furthermore, new business entities in the region have increased agricultural research and development efforts and become leaders in agricultural production. Many new grain and oil business entities in Huangzhuang Village of Yongxing Town cooperated with "Jiang Xiaobai" to increase social performance and increase local farmers' employment and income.

5 Conclusion

First, different types of new business entities had different dimensions and comprehensive projection values. Specifically, the development potential dimension was 0.4116–0.7571, the economic performance dimension was 0.0330–0.0370, the social performance dimension was 0.0338–0.0482, the ecological performance dimension was 0.0654–0.0786, and the development prospect dimension was 0.0433–0.0842. The ranking of comprehensive projection values, from highest to lowest, was as follows: agricultural enterprises (1.0051), farmer cooperatives (0.8135), large farmers (0.6513), and family farms (0.5972).

Second, the internal industrial development potential varied among the four types of new business entities. Fruit and vegetable agricultural enterprises had the highest development potential, followed by farmers' cooperatives, large farmers, and family farms. The grain industry represented the industry with the greatest development potential for large farmers.

Third, the high-density areas of new business entities were mainly located in Ciyun Town and Shimen Town. There were differences in the high-density areas and kernel density values of various types of new business entities with different potentials. The kernel density value of agricultural enterprises from big to small was categorized as high potential, low potential, and medium potential. There were few discrepancies in the kernel density values of farmers' cooperatives. The kernel density value of family farms was highest for low potential, followed by medium potential, and lowest for high potential. In addition, the kernel density values of large farmers were small.

Finally, the villages in the research area were divided into five types of new business entity development potential areas: low development potential area, relatively low development potential area, normal development potential area, relatively high development potential area, and high development potential area. Of these, the low development potential area accounted for 29.41% of all villages, the relatively low development potential area accounted for 16.18% of all villages, the normal development potential area accounted for 27.94%

of all villages, the relatively high development potential area accounted for 16.18% of all villages, and the high development potential area accounted for 10.29% of all villages.

The cultivation of new agricultural management entities by regional differentiation not only guarantees their green and sustainable development but also provides the endogenous impetus for the transformation and upgrading of agriculture and modernization. Research involving new agricultural business entities can promote the process of agricultural modernization and achieve rural revitalization. However, this study does not analyze the dynamic change characteristics of the development potential of different industries among various new business entities. Further research is needed to understand the spatial and temporal change patterns of different industries within different types of new business entities.

6 Policy implications

New business entities in the study area can be developed from multiple perspectives to enhance the level of industrialization. First, a circular agriculture model for the planting model may be used, maximizing the use of land and time. In addition to developing new products, expansion of the use of pepper by-products in various applications such as feed, paper, fertilizer, fuel, activated charcoal, and handicrafts may enhance the level of industrialization of new business entities. Second, the mountains and water bodies in the study area can provide benefits to human beings and be used to explore local culture and develop various products. The increase in production, processing, and sales enhances tourism as part of an industrial chain to increase efficiency. Third, the government may make special funds available and formulate agricultural policies every year to stimulate leading enterprises to innovate in science and technology, better integrate information technology construction with traditional processing, and promote the formation of enterprise level automation and intelligence level, so that the new business entity industry spreads to the recreation and healthcare sectors, bio-medicine, daily chemical raw materials, biopesticides, and other products to accelerate the new business entity and enhance the level of industrialization.

At present, rapidly developing new business entities have reached a bottleneck, and increasing development funds and increasing policy support to break through the existing achievements have a greater role in promotion. To implement the spirit of Central Document No. 1 on supporting agricultural and rural projects and better promote the development of new business entities in the study area, it is important to first develop government policy, increase financial support, and establish a sound policy support mechanism. This involves strengthening the organizational leadership, including expert teams and party and government personnel. This also involves the implementation of the quality of farmers to help the system and stimulating the enthusiasm of new business subject organization, aiding households through economic subsidies. This also involves ensuring the availability of professionals to offer consulting services, access to technical lectures on a yearly basis, the availability of technicians to offer guidance on planting and management techniques, and the transfer of knowledge to practical results, to increase incomes. The government should help to set up organizations to strengthen the quality supervision of new business entities, increase public awareness, issue initiatives, post signs, and regularly interview processing subjects and dealers. Further recommended initiatives include setting up a joint law enforcement group to organize the District Public Security Bureau and the District Agricultural Committee and other departmental personnel to conduct joint management actions on the sanitary side. Through precise investment attraction, entities from neighboring provinces and cities will be introduced to high-quality new businesses, and the introduction of favorable policies will stabilize these new business entities for a long time and enable the benign development of new business entities.

Data availability statement

The datasets generated or analyzed during this study are available from the corresponding author on reasonable request. Requests to access the datasets should be directed to the corresponding author.

Author contributions

SZ: Conceptualization, Data curation, Funding acquisition, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. XuZ: Methodology, Visualization, Writing – review & editing. JL: Visualization, Writing – review & editing. XiZ: Writing – review & editing. YL: Writing – review & editing.

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Conflict of interest

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

Publisher's note

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