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Agricultural socialized services and grain yield per unit area: empirical evidence from Jiangxi Province, China

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Objective: Given limited cultivated land resources, increasing grain yield per unit area is crucial to ensure food security. Although China's total grain production has increased for 20 consecutive years and remained above 6.5×10^8 t for nine consecutive years, the contribution rate per unit yield still needs to be improved. Agricultural socialized service is essential in promoting sustainable food production in China, which can drive land cultivation and grain increase.

Methods: Using survey data from 893 rice farmers in Jiangxi Province, China. This paper adopted the OLS model and intermediary effect model to explore the impact of agricultural socialized service on grain yield per unit area and its mechanism and further analyzed the heterogeneity of agricultural socialized service adoption on grain yield per unit area under different regions, farmland, and farm household types.

Results: (1) Agricultural socialized service had a significant positive effect on grain yield per unit area, which passed the endogeneity and robustness tests. (2) The adoption of agricultural socialized services by farmers will enhance the machinery use of the rice production process, promote the large-scale development of agricultural operations, and drive the "grain-oriented" planting structure, thereby achieving an increase in grain yield per unit area. (3) The heterogeneity test showed that agricultural socialized service had a more significant effect on promoting grain yield per unit area of farmers in grain-producing counties, farmers with low land fragmentation degree, farmers with a high degree of part-time employment and farmers with strong digital ability.

Conclusion: This study emphasizes the potential of agricultural socialized services for grain yield per unit area and plays a crucial role in ensuring food security. By attaching importance to the supply–demand side benefits of agricultural social services, improving the availability of agricultural social services, and guiding farmers to cultivate grain scientifically, policymakers can use these insights to formulate targeted measures and fully exploit their optimal benefits.

KEYWORDS

agricultural socialized services, grain yield per unit area, machinery use, moderate scale operation, planting structure

1 Introduction

With the continuous global population growth and the accelerated pace of industrialization and urbanization, sustainable agricultural development has assumed an increasingly pivotal role (Satterthwaite et al., 2010; Yu and Wu, 2018). Within the framework of the Sustainable Development Goals (SDGs) established by the United Nations for 2030, eliminating all hunger and malnutrition is a target, which reflects the international community's heightened emphasis on food security. However, multiple factors, including international trade volatility, frequent extreme weather, and others, currently challenge the global food system's ability to provide nutritious food (Bureau and Swinnen, 2018; Prosekov and Ivanova, 2018). Therefore, it is particularly important to increase food production, which is directly related to the stability of food security. For a long time, improving yield per unit area and expanding sown area have been important factors to promote grain yield increase (Chen et al., 2011; Emran et al., 2021). In 2023, research by the Organization for Economic Cooperation and Development (OECD) and the Food and Agriculture Organization of the United Nations (FAO) shows that the contribution rate of increase in yield per unit area to the global crop increase in the next 10 years will be 79%, the contribution rate of expansion of cultivated land area will be 15%. The increase in unit yield means that more food can be produced in the same unit area of land, and it is also an inevitable choice for the sustainable development of global food in the future (Cheng et al., 2007). As one of the world's largest population and grain production countries, China's food security situation has improved, achieving a historic 20 consecutive years of bumper harvests. However, at this stage, the grain increase mainly relies on many pesticides, fertilizers, and other inputs, and the contribution rate of science and technology is low. In a typical sign, the grain yield per unit area has increased by only 3.14% in the past decade (Qian et al., 2024). While promoting total output growth, this model also shows an obvious unsustainability problem, quickly leading to cultivated land degradation and other consequences (Wu et al., 2024). By 2030, China's total population is expected to reach 1.45 billion, when there will still be 360 million people living in the countryside; according to 1.8 billion acres of arable land does not reduce farmers per capita 5 acres of land, the average household is only 20 acres. Therefore, in the limited cultivated land resources, reversing the slow growth of grain yield per unit area to ensure sustainable grain production is an urgent issue that needs immediate attention.

Given its fundamental and strategic position, food production has been widely gaining attention from academic circles. On the one hand, it is affected by the endogenous factors of production such as grain variety (Mackill and Khush, 2018), scale of operation (Li et al., 2023), agricultural insurance (Kurdyś-Kujawska et al., 2021), labor force structure (Alvarez- Cuadrado and Poschke, 2011), planting training (Kansanga et al., 2021), and others. On the other hand, it is affected by exogenous economic factors such as regional economic development level (Tiwari and Joshi, 2012), food policy support (Boratyńska and Huseynov, 2017), and others. Rapid industrialization and urbanization have led to productive resources, "capital, workforce, and technology, "predominantly in urban areas, particularly in developing countries where this trend persists (Chen et al., 2022). To address these difficulties in food production, the agricultural service industry has gradually emerged; its purpose is to serve agriculture and farmers. The agricultural service industry usually refers to providing full industrial chain services for farmers relying on multiple service entities such as professional economic departments, rural cooperative organizations, and leading agricultural enterprises. Cooperatives, service organizations, etc., cover a large part of the agricultural sectors and could, therefore, play a role in improving food production sustainability (Candemir et al., 2021). For instance, the establishment of farmer producer organizations in India has provided collective support and services for smallholder farmers, which can enhance agricultural productivity (Bikkina et al., 2018); Agricultural extension services in Pakistan aim to address issues related to agricultural production and management (Baloch and Thapa, 2019); The practice in Ethiopia has proved that extension services not only contribute to the sustainable development of agriculture, but also help farmers switch to more commercial, market-oriented agriculture (Buehren et al., 2017), etc. Given this, China's agricultural socialized services refer to the agricultural production services provided by the service subjects for developing Chinese farmers in various sectors such as planting, forestry, animal husbandry, and fishery. The government has issued a series of relevant policies to support the development of agricultural socialized services (Lu et al., 2023). By the end of 2023, there were 1.094 million agricultural socialized service organizations in China, covering an area of 142.67 million hectares; among them, the area of grain crops reached 107.34 million hectares, driving over 94 million small-scale farmers to increase their income. The No.1 Central Document has proposed for many years to strengthen the construction of the agricultural science and technology socialized service system.

The issues related to agricultural socialization service and food production have been widely discussed in academic circles. Under the framework of collective ownership of rural land, agricultural socialized services can save the agrarian labor force, reduce the abandonment of cultivated land by farmers, promote the rational protection of cultivated land, and facilitate the development of sustainable agriculture (Huan et al., 2022; Yang et al., 2024). Promoting farmers' grain-growing behavior will also drive farmers' large-scale grain operations, increase the total grain output and raise the agricultural income of farmers' families (Mi et al., 2020; Li et al., 2024). Regarding production efficiency, Deng et al. (2020) research found that productivity increased by 25.61% for farmer households who choose to outsource. Moreover, if nonoutsourcing farmer households would choose to outsource, their productivity would increase by 10.86%. Further, Cai et al. (2024) analyzed different crops and revealed that agricultural socialized services have a relatively noticeable promoting effect on the production efficiency of rice. Most studies have confirmed that agricultural socialized services positively impact food production (Picazo-Tadeo and Reig-Martínez, 2006); compared with traditional agriculture, agricultural socialized services can help farmers participate in more efficient food production while maintaining land rights and income (Cai et al., 2024), and this impact has been increasing over time (Lu and Du, 2020). However, agricultural socialized service organizations may have potential moral hazard issues. In this principal-agent relationship, the interests of farmers (as demand entities) and service providers (as supply entities) are not fully aligned (Pandey et al., 2013; Qu et al., 2022). Concurrently, with the escalating costs of agricultural socialized services, the break-even time of the sunk costs of small-scale farmers is relatively long, thereby failing to promote grain production effectively (Qiu et al., 2021). Then, under the condition of "low profit" from growing grain

for farmers, how agricultural social services can be effectively applied to agricultural production to increase the per-unit yield of grain remains to be further studied.

Existing literature has laid a theoretical foundation for this study, and some areas still need to be further developed: (1) Although there are many studies on agricultural socialization services and food production, food production capacity is mostly examined from the perspective of food production efficiency and total output. (2) Regarding the research content, there is a relative lack of mechanism analysis on the impact of agricultural socialized services on the per-unit grain yield. (3) It is generally recognized that the effectiveness of agricultural social services is universally applicable. However, the impact and effect of agricultural social services adopted by farmers with different environments and characteristics are inconsistent, and a unified service promotion policy may lead to resource waste. Then, this paper is deepened from the following three points: (1) The issue of grain increase from the perspective of grain yield per unit area, and elucidate the mechanism between agricultural socialized services and grain yield per unit area to provide a more specific and more realistic understanding of China's agricultural background. (2) Further, it explores the interaction mechanism between agricultural socialized services and grain yield per unit area and expands the theoretical understanding of their relationship. (3) Explores the heterogeneity of farmers' adoption of agricultural socialized services on grain yield per unit area under different regions, farmland, and types, and to develop agricultural social services according to local conditions and different persons is conducive to achieving the best benefits. Based on this, utilizing micro-survey data from 893 rice farmers in Jiangxi Province in 2023, this paper constructs a benchmark regression model to analyze the impact of agricultural socialized services on grain yield per unit area. Moreover, it incorporates the use of machinery, scale of operation and planting structure to examine their mediating mechanisms. Finally, further discussion of the heterogeneous effects of agricultural socialized services and grain yield per unit area.

2 Theoretical analysis

The multi-objective utility theory supposes that farmers do not pursue a single path or goal in their agricultural production decisions, and implementing each decision will follow the logic of overall utility maximization (Li et al., 2024). The emergence of agricultural socialized services can replace the purchase of agricultural facilities and equipment. This innovative approach not only reduces the cost of improving operational efficiency but also solves the bottlenecks that farmers may encounter in the process of grain cultivation (Zhou, 2017; Huan et al., 2022). From the perspective of specialization, agricultural socialized services are essentially the result of the deepening of the agricultural production division of labor. By integrating production activities with a high degree of asset specialization into the social division of labor system, a specialized division of labor is conducive to increasing the total output of grain crops within the same sown area (Erdkamp, 2015; Liu et al., 2019). From the perspective of modernization, agricultural socialization services assist in completing the operations of each link in agricultural production in accordance with its own comparative advantages, and optimize the allocation of modern production factors in the process of grain planting. Accelerate the agricultural production process, shorten agricultural busy periods, mitigate agricultural production risks, minimize crop growth losses, and contribute to the incremental improvement of agricultural production quality (Rehman et al., 2016). From the perspective of technologization, the technological diffusion effect of agricultural socialized services can further guide farmers to grow food crops efficiently. Specifically, professional service entities can complete operations such as land preparation, fertilization, and pesticide spraying, which can enhance the scientific precision of agricultural production and mitigate the elevated production costs caused by soil degradation in subsequent production (Cheng et al., 2022). Therefore, entrusting agricultural production links to professional agricultural socialized service providers can help farmers reduce production costs as a whole, break through the obstacles of production factors, management methods, and scientific and technological levels, improve grain production capacity, and foster the increase of grain yield per unit area to ensure the sustainability of agricultural production.

> *Hypothesis 1 (H1):* The adoption of agricultural socialized service in rice production can promote the increase of farm household grain yield per unit area.

The theory of induced technological change states that resource scarcity triggers changes in the relative prices of production factors, thereby inducing technological innovation and factor substitution (Zheng and Xu, 2017). The "labor scarcity type" is suitable for using mechanical technology to save labor input. Food production is labor intensive, requiring substantial human resources across various production stages (Yi, 2018; Yang and Li, 2022). Mature agricultural socialized services can effectively mitigate farmers' information acquisition costs, agricultural machinery negotiation expenses, and operational supervision expenditures. By horizontally integrating individual farmers to expand service groups, realize centralized purchase, unified operations, and cost-sharing. Without having to purchase their agricultural machinery, use machinery in more production stages (Li et al., 2024), and improve production mechanization levels. Using machinery in more production links at a lower cost and increasing capital investment by farmers in land management to replace labor input is conducive to effectively alleviating the labor shortage problem in intensive grain production (Yang and Zhang, 2023). Machinery production is the performance of modern agricultural production transformation (Emami et al., 2018). Compared with manual operation, the use of machinery not only reduces agricultural labor intensity and per-unit labor inputs, makes agricultural production more efficient, and improves grain management quality. High-performance machinery enables precision operations, optimizing the utilization efficiency of input factors such as seeds and fertilizers, increasing agricultural land output, and improving the unit profitability of grain production (Takeshima et al., 2013; Liu and Li, 2023).

> *Hypothesis 2 (H2):* Farm households adopt agricultural socialized services to promote the increase of grain yield per unit area by improving the machinery use of rice production.

The transfer of agricultural land can alleviate the tension between population and land resources, conducive to the realization of large-scale and intensive agricultural production, and serves as the primary

driving force of moderate-scale farm operations in China (Fei et al., 2021). Agricultural socialization services can help rational farmers achieve optimal alignment between agricultural production capacity and operational scale (Yang and Zhang, 2023). Integrating small-scale farmers and attracting large-scale operation entities to centralize scattered land through land transfer effectively enhances the marginal returns on land scale through the rational allocation of production factors, further strengthening farmers' willingness and behavior of scaled land management (Cai et al., 2021; Zhou et al., 2023). Although most studies suggest that the scale-per-unit yield relationship of Chinese farmers is an inverted U-shaped relationship (Zhang and Wang, 2021; Zheng et al., 2024), to maximize household income, farmers will optimize the allocation of labor force and release some labor and capital for non-agricultural employment. Therefore, the expansion of business scale is usually within a moderate range and does not exceed the critical value (Zheng et al., 2024). Moderate-scale operations mitigate extensive management practices resulting from either excessively small or large operational areas, facilitate the implementation of scientific planting standards, promote compatibility with local resource conditions, and better harness the benefits of scale operations (Deolalikar, 1981; Rada and Fuglie, 2019). Its role in ensuring food security has become increasingly prominent (Fan and Zhou, 2014). In summary, by adopting agricultural socialized services, farmers have promoted moderate-scale operations in agriculture, achieved Pareto improvements, and increased the grain yield per unit area.

> *Hypothesis 3 (H3):* Farm households adopt agricultural socialized services to promote the increase of grain yield per unit area by guiding rice management on a moderate scale.

Compared with economic crops, producing food crops such as rice demonstrates greater scalability potential. Implementing agricultural socialized services helps alleviate the constraints on farmers' planting of food crops and enhances their willingness to grow food crops (Xu et al., 2025). Scott's "risk aversion" theory posits that agricultural producers are not solely driven by rationality and profit maximization but are equally concerned with survival and safety considerations. Although economic crops may generate high returns, they require more technological investment, human resources, longer growing cycles, and significant initial capital investment. The demand for food crops is relatively rigid, and their prices are relatively stable compared to other economic crops (Zhang, 2020; Guo et al., 2022). Agricultural socialized services can augment food crop cultivation benefits through "cost reduction and efficiency enhancement," stimulating farmers' enthusiasm for food crop production and subsequently influencing their cultivation behaviors (Daohe et al., 2025). The "grain-oriented" planting structure facilitates the intensive, specialized, and organized development of grain production, optimizing field management practices, which can help enhance production efficiency and promote increased grain yield per unit area (Liu et al., 2019; Yuan et al., 2021). Consequently, farmers' adoption of agricultural socialized services contributes to the promotion of grain cultivation behaviors and further increases per unit grain yield (Figure 1).

> *Hypothesis 4 (H4):* Farm households adopt agricultural socialized services to promote the increase of grain yield per unit area by increasing the proportion of grain cultivation.

3 Data and methods

3.1 Data

Jiangxi Province, located on the south bank of the middle and lower reaches of the Yangtze River, is one of China's 13 prominent grain-producing areas. In 2023, the grain sown area of Jiangxi Province will be 3.776 million hectares, a decrease of 2067.7 hectares over the previous year. The total output was 21.895 million tons, an increase of 465,000 tons over the previous year. The yield of grain crops per mu was 388.3 kg, an increase of 8.4 kg over the previous year, and the rice output ranked third in the country. "Increase grain production through soil conservation and technology" is important for a stable and high grain yield in Jiangxi Province. Since 2023, Jiangxi Province's supply and marketing cooperative system has led the establishment of 140 specialized agricultural machinery cooperatives, aggregated 8,932 sets of agricultural machinery and equipment, and carried out 2,324,700 hectares of agricultural socialized production services. Therefore, selecting Jiangxi Province

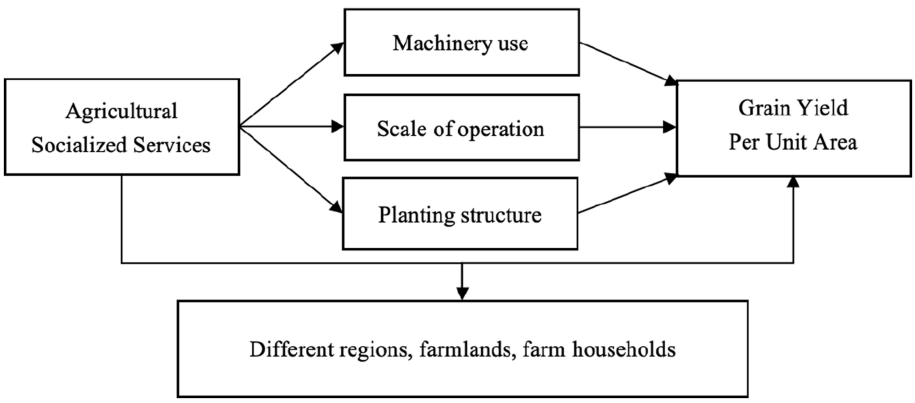

FIGURE 1
Theoretical framework diagram.

as the research area on the influence of agricultural socialized service on grain yield per unit area is representative and reliable.

The data used in this study is derived from the "Double Hundred and Double Thousand" survey data for rural revitalization in Jiangxi Province. This is the household survey data of the rural revitalization platform project conducted by the Jiangxi Rural Revitalization Strategy Research Institute of Jiangxi Agricultural University from June to July 2023. The research employed a stratified random sampling approach, selecting 24 counties from 11 prefecture-level cities in Jiangxi Province, stratified by economic development levels. Subsequently, three townships were randomly selected from each county, three administrative villages from each township, and ten households from each village, accumulating a total sample of 72 townships, 216 administrative villages, and 2,160 households. The geographical distribution of the study areas is illustrated in Figure 2. The research contents include the following three aspects: (1) the sowing area of single-season rice and double-season rice; Yield of early rice, middle rice, and late rice. (2) The adoption of agricultural socialized services and machinery in seedling, plowing, sowing, fertilizing, spraying, and harvesting. (3) Individual characteristics of respondents, basic characteristics of farm households, production and management characteristics, and village characteristics. This study screened 1,440 samples of farmers who engaged in rice production in 2022, eliminated missing values and outliers in the samples, and finally obtained 893 samples, accounting for 62.01% of the rice production farmers.

3.2 Variables selection

3.2.1 Explained variable

The dependent variable of this article is grain yield per unit area. According to research by Ning et al. (2024), the area of two sowing modes of single rice cropping and double rice cropping and the yield per unit area of early rice, mid-season rice, and late rice were selected to measure grain yield per unit area.

$$Yield = \frac{y_{sinlge} + y_{double}}{S_{single} + S_{double}} \quad (1)$$

In Equation 1: y_{sinlge} refers to one of the early indica, mid-season, single-season late rice. y_{double} refers to the planting of late rice after the early rice is harvested. S_{single} refers to the sown area of single rice cropping. S_{double} refers to the sown area of double rice cropping. Given that rice cultivation in most regions of Jiangxi Province occurs no more than twice annually. Therefore, the error value that does not comply with the planting pattern is eliminated.

3.2.2 Explanatory variable

The explanatory variable of this article is agricultural socialized services. According to research by Yang and Zhang (2022), the number of agricultural socialized services adopted by farmers across various stages of rice production, including seedling, plowing, sowing,

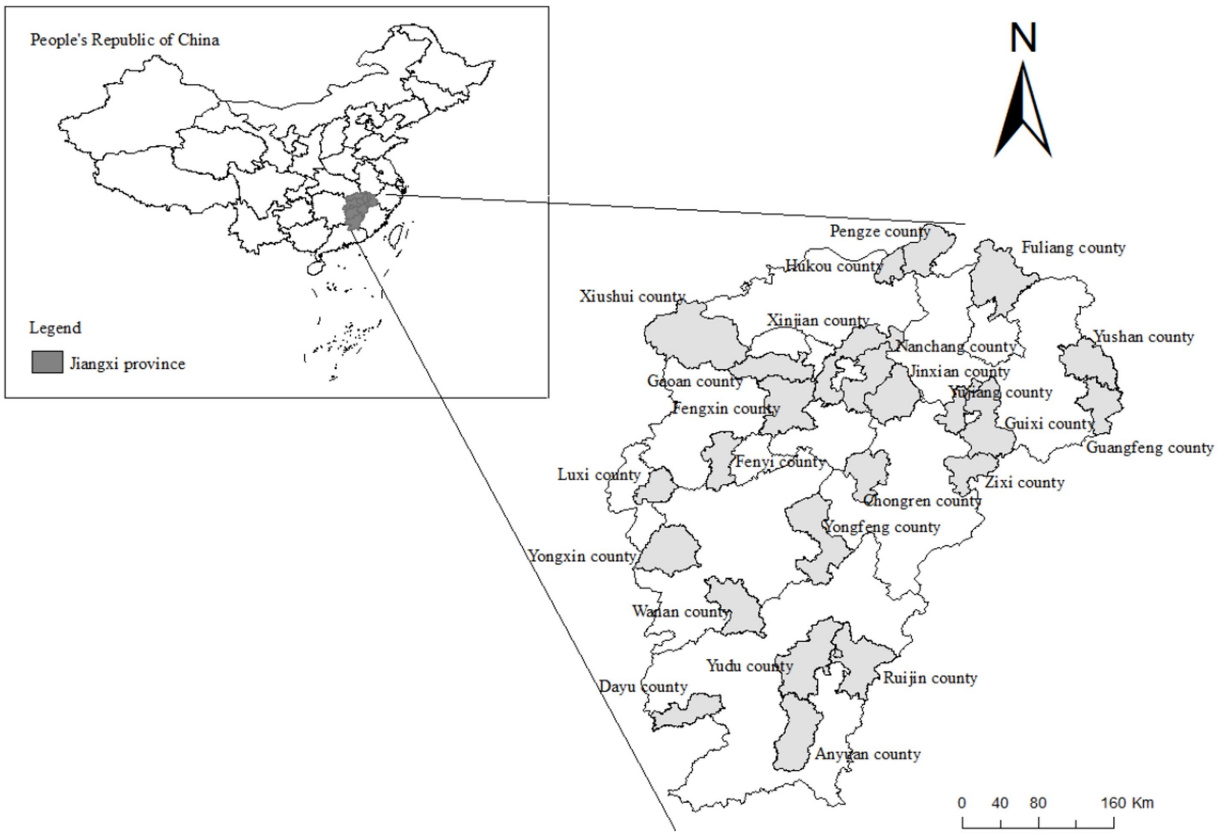

FIGURE 2
Location of the study areas in Jiangxi Province, China.

TABLE 1 Descriptive statistical analysis of variables.

Variable name	Variable assignment	Mean	SD[a]	Max	Min
Grain yield per unit area	Rice yield per hectare(t/hm^2)	7.613	3.099	18.750	2.250
The degree of adoption of agricultural socialized services	The number of agricultural social services used in rice production	1.723	1.340	6.000	0.000
Machinery use	Share of machinery use in total workload	0.339	0.180	1.000	0.000
Scale of operation	Rice management area(hm^2)	2.403	10.118	167.500	0.007
Planting structure	Rice planting area/crops' planting area	0.703	0.256	1.000	0.048
Sex	Female = 0, male = 1	0.821	0.384	1.000	0.000
Age	Age of respondent (years)	58.345	10.974	87.000	23.000
Education level	No schooling = 1, elementary school = 2, junior high school = 3, high school = 4, college and above = 5	2.858	0.963	5.000	1.000
Village cadre identity	Not village cadres = 0, village cadres = 1	0.264	0.441	1.000	0.000
Number of annual farmers	The number of family members working in agriculture exceeds half a year	1.573	0.905	8.000	0.000
Rice planting training	Not participated = 0, participated = 1	0.263	0.441	1.000	0.000
Plot area	The ratio of managed land area to the number of plots(plot/hm^2)	0.409	2.226	36.850	0.005
Pesticide expenditure	Pesticide expenditure per unit of rice planting (Ten thousand yuan/hm^2)	0.177	0.175	0.896	0.000
Fertilizer expenditure	Fertilizer expenditure per unit of rice planting (Ten thousand yuan/hm^2)	0.386	0.358	2.239	0.000
Village topography	Plain = 1, hilly = 2, mountainous = 3	1.825	0.609	3.000	1.000
Village in town economic level	Very low = 1, relatively low = 2, average = 3, relatively low = 4, very low = 5	3.303	0.711	5.000	2.000
Village traffic conditions	Very poor = 1, relatively poor = 2, average = 3, relatively good = 4, very good = 5	3.885	0.852	6.000	1.000
Northern Jiangxi (with Southern Jiangxi as reference)	Whether it is North Jiangxi, no = 0, yes = 1	0.586	0.493	1.000	0.000
Central Jiangxi (with Southern Jiangxi as reference)	Whether it is central Jiangxi, no = 0, yes = 1	0.254	0.436	1.000	0.000

fertilizing, spraying, and harvesting, is taken as an index to quantify the degree of adoption of agricultural socialized services. The value of non-adoption is 0, and the value of agricultural socialized services adopted by any one link is 1, 2 link adoption is 2, 3 link adoption is 3, 4 link adoption is 4, 5 link adoption is 5, and 6 link adoption is 6.

3.2.3 Mediating variables

With reference to existing literature, the mediating variables in this article are machinery use (Li et al., 2024), scale of operation (Cai et al., 2021) and planting structure (Peng et al., 2021). The proportion of machinery farmers use in the rice production process to the total workload is taken as the indicator for measuring machinery use. Farmers' rice acreage measures the scale of operation. The planting structure is measured by dividing each household's rice planting area by the crops' actual planting area.

3.2.4 Control variables

To mitigate potential model estimation bias arising from omitted variables, according to research by Lu et al. (2023) and Cai et al. (2024). Individual characteristics include gender, age, educational level, and village cadre status. Management characteristics include the number of members in the household engaged in farming, participation in rice planting training, Plot area, average pesticide expenditure per unit, and average fertilizer expenditure per unit. Village characteristics include topographic features, economic standing within the township, transportation infrastructure, and geographical location (Table 1).

3.3 Sample characteristics

Table 2 shows the basic characteristics of sample farmers: The proportion of male farmers in the sample is 82.08%, and their ages are mainly distributed in the two ranges of 56–64 years old and 65 years old and above, accounting for 31.02 and 31.69%, respectively. Most of them are middle-aged and older adults. Those with high education levels are primary school education and junior middle school education, accounting for 32.70 and 39.64%, respectively, and their education level is low. 73.57% of rural farmers are not village cadres. The majority of households have two or fewer family members engaged in farming annually, accounting for 94.96%; most members tend to engage in non-agricultural work. Only 26.32% of farmers have participated in rice planting training. 76.82% of households cultivate farmland fields of 0.67 hm2 or less; the farmland plots number is

TABLE 2 Statistical characteristics of survey samples.

Characteristic	Options	Observations	Percentage (%)	Characteristic	Options	Observations	Percentage (%)
Sex	Male	733	82.08%	Number of annual farmers (persons)	≤2	848	94.96%
	Female	160	17.92%		3 ~ 5	41	4.59%
Age (years)	≤35	34	3.81%		≥6	4	0.45%
	36 ~ 45	64	7.17%	Rice planting training	Yes	235	26.32%
	46 ~ 55	235	26.32%		No	658	73.68%
	56 ~ 64	277	31.02%	Scale of farmland operation (hm^2)	≤0.67hm^2	686	76.82%
	≥65	283	31.69%		0.67hm^2 ~ 1.33hm^2	59	6.61%
Education level	No schooling	46	5.15%		1.33hm^2 ~ 2hm^2	20	2.24%
	Elementary school	292	32.70%		≥2hm^2	128	14.33%
	Junior high school	354	39.64%	Number of farmland plots of a household (plots)	≤2	271	30.35%
	Senior high school	145	16.24%		3 ~ 5	334	37.40%
	College and above	56	6.27%		6 ~ 8	134	15.01%
Village cadres	Yes	236	26.43%		≥9	154	17.25%
	No	657	73.57%				

mainly 3 ~ 5, accounting for 37.40%. According to the above analysis, the samples selected in this study are basically consistent with the current situation of rural areas in Jiangxi Province, and the samples are relatively scientific, reasonable, and representative.

In the conventional cultivating of rice in southern China, the yield of low-yielding rice fields is generally 4.5 t/hm^2 ~ 5.25 t/hm^2, and that of high-yielding rice fields is generally 7.5 t/hm^2 ~ 9 t/hm^2. The specific yield is affected by cultivar., season, region, management method, and other factors. Therefore, the rice yield below 5.25 t/hm^2 is classified as a low-yield rice field, 5.25 t/hm^2 ~ 7.5 t/hm^2 is classified as a middle-class rice field, and above 7.5 t/hm^2 is classified as a high-yield rice field. Table 3 reports the cross-analysis of the adoption degree of farmers' agricultural socialized service and rice yield per unit area. From the perspective of adoption degree, with the increase of adoption degree, the number of farmers decreases, whether it is low-yield rice field, middle-class rice field, or high-yield rice field, indicating that there are fewer farmers with a high degree of agricultural socialization adoption at present, and the adoption degree has not reached saturation. Moreover, from the perspective of low-yield, middle-class, or high-yield rice farmers, the proportion of high-yield rice farmers who did not adopt agricultural socialization services was slightly higher than that of low-yield and middle-class rice farmers. The proportion of those who adopted 1 ~ 3 kinds of high-yield rice farmers was higher than that of low-yield rice farmers and middle-class rice farmers. The proportion of farmers who adopt 4 ~ 6 kinds of high-yield rice fields is much higher than that of low-yield rice fields and middle-class rice fields. It can be seen that with the improvement of the social adoption of agriculture, the number of high-yield rice farmers is also increasing.

3.4 Model construction

The study employs the OLS model to estimate the impact of agricultural socialization services on grain yield per unit area. The specific model formulation is as follows:

$$Y_i = \alpha_0 + \alpha_1 ASS + \alpha_2 X_i + \varepsilon_i \quad (2)$$

In Equation 2: Y_i represents the rice yield per unit area in farmer households. ASS represents the degree of adoption of farmers' agricultural socialized services. X_i includes a series of control variables mentioned above. α_0, α_1, α_2 are the parameters to be estimated. ε_i is the random error term.

To examine the mechanism through which agricultural socialization services influence grain yield per unit area, this paper adopts the mediation effect test steps provided by Ting (2022), building upon the foundation of Model (2):

$$M_i = \beta_0 + \beta_1 ASS + \beta_2 X_i + \epsilon_i \quad (3)$$

In Equation 3: M_i represents the mediating variables, including the mechanization level and scale of operation of farmer households. β_0, β_1, β_2 are the parameters to be estimated. ϵ_i is the random error term. Existing studies have demonstrated that the use of machinery, moderate-scale operation, and the "grain-oriented" planting structure positively affect grain yield per unit area, which aligns with national agricultural policies and conforms to the principles of rice production

TABLE 3 Adoption degree of agricultural socialized service and rice yield per unit area.

The adoption degree of agricultural socialized services	Low-yield rice field	Percentage (%)	Middle-class rice field	Percentage (%)	High-yield rice field	Percentage (%)
0	33	21.85%	48	31.79%	70	46.36%
1	53	22.08%	64	26.67%	123	51.25%
2	62	17.08%	135	37.19%	166	45.73%
3	11	17.74%	20	32.26%	31	50.00%
4	0	0.00%	13	44.83%	16	55.17%
5	1	5.88%	5	29.41%	11	64.71%
6	2	6.45%	10	32.26%	19	61.29%

and management. Consequently, if β_1 demonstrates statistical significance, it means that the mechanism effect exists.

4 Results

4.1 Benchmark regression analysis

Before estimating the model, this study conducted a multicollinearity test. The results indicated that each variable's maximum variance inflation factor (VIF) was 1.61, with an average VIF of 1.24, both substantially below the threshold of 10, confirming the absence of significant multicollinearity among variables. Without the addition of control variables, and with the addition of control variables including individual characteristics, management characteristics, and village characteristics, both reveal that the adoption of agricultural socialized services in grain production processes exerts a statistically significant positive impact on rice yield per unit area at the 1% significance level. The possible reason is that agricultural socialization services can concentrate resources, facilitate specialized division of labor, and enhance resource utilization efficiency in grain production. Through the unified operations and modern production mode guidance provided by service organizations, farmers experience reduced production costs, labor expenditures, and time investments while improving production efficiency and operational quality, thereby driving cost-effective and productive agricultural practices. Adopting agricultural socialization services in the grain production chain enables more resource allocation to increase grain yield, consequently increasing the grain yield per unit area.

Regarding individual characteristics, male labor demonstrates comparative advantages over female labor in the necessary grain production processes. The relaxation of population movement restrictions under the urban–rural dual system has led to an increasing number of highly educated rural laborers opting for non-agricultural employment, reducing agricultural production time and potentially inhibiting per-unit grain yield growth. Regarding management characteristics, farmers' participation in training programs facilitates the acquisition of advanced rice cultivation knowledge and skills, enabling them to adopt high-yield, pest-resistant rice varieties in production practices. The construction of high-standard farmland reduces land fragmentation, moderates land areas, and proves conducive to agricultural modernization and enhanced grain production efficiency. Appropriate pesticide application ensures rice protection against pests and diseases throughout the growth cycle, maintaining optimal growing conditions and promoting increased per unit grain yield. Regarding village characteristics, flatter terrain facilitates land contiguity, supports intensive management practices, and enables efficient utilization of large-scale agricultural machinery and irrigation facilities, typically resulting in higher per-unit grain yields than areas with complex topography. Furthermore, improvements in village economic levels contribute to increased farmer income, enabling more investment in agricultural technology acquisition and implementation, thereby promoting grain production enhancement (Table 4).

4.2 Endogeneity discussion

4.2.1 Propensity score matching

The adoption of agricultural socialized services by farmers is non-random, as their decisions are influenced by their endowments. In addition, this study deletes part of the samples according to "whether to focus on farming" and "whether to produce rice," which may lead to selective bias and limit the generalizability of the findings to the broader population. To address the issue of sample self-selection, this research employed the Propensity Score Matching (PSM) method to construct a counterfactual analysis framework, thereby enabling the estimation of the net effect of agricultural socialization service adoption while mitigating sample selection bias, including nearest neighbor matching ($k = 4$), caliper matching (caliper = 0.05), kernel matching, local linear regression matching, and Mahalanobis distance matching. In this analytical framework, farmers who adopted socialized agricultural services were classified as the treatment group, while those who did not were classified as the control group. The estimated results are shown in Table 5. Regardless of the matching method, the Average Treatment Effect on the Treated (ATT) of agricultural socialized service adoption on grain yield per unit area remains consistently positive and statistically significant; the treatment group exhibited significantly higher grain yields per unit area than the control group. Further, as shown in Figure 3, the balance test results show minimal difference between all treatment and control groups, with the absolute standardized deviation of all covariates below 10%. This confirms the validity of the five matching processes. Pre- and post-matching standard deviation plots demonstrate the consistency of the variables, providing robust support for the benchmark regression findings.

TABLE 4 Benchmark regression estimation results.

Variable	No control variable was added	Add control variable
The degree of adoption of agricultural socialized services	0.458*** (0.09)	0.296*** (0.09)
Sex		0.874*** (0.26)
Age		−0.011 (0.01)
Education level		−0.202* (0.11)
Village cadre identity		0.102 (0.25)
Number of annual farmers		0.099 (0.12)
Rice planting training		0.814*** (0.26)
Plot area		0.173** (0.07)
Pesticide expenditure		1.336* (0.79)
Fertilizer expenditure		−0.249 (0.33)
Mountain (with plain as reference)		−0.298 (0.34)
Hills (with plain as reference)		0.573* (0.32)
Village in town economic level		0.384** (0.16)
Village traffic conditions		0.155 (0.11)
Northern Jiangxi (with Southern Jiangxi as reference)		0.907*** (0.25)
Central Jiangxi (with Southern Jiangxi as reference)		0.898*** (0.33)
Constant	6.823*** 0.16	4.131*** (0.99)
Observations	893	893
R-squared	0.039	0.127

The *, **, and *** in the upper right corner of the coefficient indicate statistical significance at the level of 10, 5, and 1% respectively, and marginal effect and standard error are reported (in brackets) (the same as following tables).

4.2.2 Instrumental variable estimation

There may be reverse causality in the study of the impact of agricultural socialization service on grain yield per unit area. Therefore, this paper selected "the average amount of agricultural socialization service adopted by other farmers in the village" as the instrumental variable and used the two-stage least square method (2SLS) to estimate the model. Considering that other farmers in the village adopt agricultural socialized services in the grain production process may bring better benefits, forming a "peer effect" and encouraging farmers to accept socialized agricultural services. Then, increase the number of their adoption of agricultural socialized services, which satisfies the relevant condition. Meanwhile, the average level of socialized agricultural services adopted by other village farmers is unlikely to directly influence individual grain yield per unit area, thus satisfying the exogenous requirement. The Durbin–Wu–Hausman test significantly rejected the null hypothesis that "all explanatory variables are exogenous," indicating that the model has an endogeneity problem and is suitable for 2SLS regression. The results are shown in Table 6. The first-stage regression results show that there is a significant positive correlation between instrumental variables and potential endogenous variables at the level of 1%. The F-statistic of 25.446 in the weak instrument test at the 1% statistical level, exceeding the critical value of 16.38 at the 10% bias level, proves that the

TABLE 5 Results of propensity score matching (PSM).

Matching method	Treatment group	Control group	ATT	Standard Error	T Value
Unmatched	7.758	6.901	0.856***	0.275	3.11
Nearest neighbor matching ($k = 4$)	7.696	6.917	0.779***	0.243	3.20
Caliper matching (caliper = 0.05)	7.696	6.927	0.769***	0.232	3.31
Kernel matching	7.696	6.924	0.772***	0.232	3.33
Local linear regression matching	7.696	7.081	0.614**	0.273	2.25
Mahalanobis distance matching	7.758	7.070	0.688***	0.243	2.83

The *, **, and *** in the upper right corner of the coefficient indicate statistical significance at the level of 10, 5, and 1% respectively.

instrumental variables selected in this paper are effective. The second-stage regression results reveal that the coefficient direction of the instrumental variable aligns with that of the benchmark model, thereby verifying the research hypothesis H1 and confirming that the empirical results in this paper are reliable.

4.3 Robustness testing

4.3.1 Replacement estimation model

Rice production is mainly affected by natural factors, and rice yield per unit area is generally bilateral restricted data. Therefore, the Tobit model replaces the OLS model for regression analysis, with the results shown in Table 7 (1). The results showed that adopting agricultural socialization services exerts a statistically significant positive impact on rice yield per unit area at the 1% significance level while controlling for other variables. The degree of farmers' adoption of socialized agricultural services in rice production positively correlates with rice yield per unit area, indicating that the above-mentioned benchmark regression results were robust.

4.3.2 Alternate explanatory variable

The total expenditure of agricultural socialized services is an alternative metric to measure farmers' utilization of agricultural socialized services in food production. Therefore, the total expenditure on agricultural social services replaces the degree of adoption of agricultural social services (Yang et al., 2019), as shown in Table 7 (2). The results showed that under the premise of keeping other control variables unchanged, the utilization of agricultural socialized services had a significant positive effect on rice yield per unit area and was statistically significant at a 5% level, which further corroborates the robustness of the study's results.

4.3.3 Reduce the sample size

Considering that adopting agricultural socialization services in rice production necessitates specific cognitive capabilities from farmers, elderly farmers exhibit slower acceptance and comprehension of these services (Zeng and Shi, 2021). Farmers aged 65 years or above are classified as elderly farmers, and their samples were excluded from the regression analysis. The results are shown in Table 7 (3). The results showed that after reducing the sample size and maintaining other control variables constant, the adoption degree of agricultural socialized services continues to significantly enhance rice yield per unit area at the 1% significance level, thereby proving the robustness of the prior research results.

4.4 Mechanism analysis

The preceding analysis has substantiated that the degree of adoption of agricultural socialized services exerts a significant positive impact on the enhancement of grain yield per unit area. To further analyze the mechanism of the effect of agricultural socialized service on the increase of grain yield per unit area, this study selects machinery use, operation scale, and planting structure as mediating variables to validate the pathways of this effect. The findings are presented in Table 8.

4.4.1 Machinery use

The results are shown in Table 8 (1). At the statistical level of 1%, the adoption degree of agricultural socialized services significantly affects machinery used in the rice production process, with a coefficient of 0.077. This indicates that adopting agricultural socialized services in the production process significantly improves the use of machinery by replacing manual labor with machinery. Existing literature corroborates that agricultural mechanization is beneficial to food production. Agricultural mechanization can mitigate soil water evaporation and soil erosion, improve soil structure, increase organic matter content, and promote grain yield increase through technologies such as "deep soiling" and "less and no-tillage" (Paudel et al., 2019). Agricultural mechanization has been found to enhance grain production capacity, improve production efficiency, and thus increase grain yield per unit area (Liu and Li, 2023). Hypothesis H2 is thereby validated.

4.4.2 Scale of operation

The results are shown in Table 8 (2). At the statistical level of 1%, the adoption degree of agricultural socialized services significantly affects the scale of rice production and management, with a coefficient of 0.943. This indicates that the adoption of agricultural social services by farmers can help rational farmers promote the matching of agricultural production capacity with management scale, and achieve

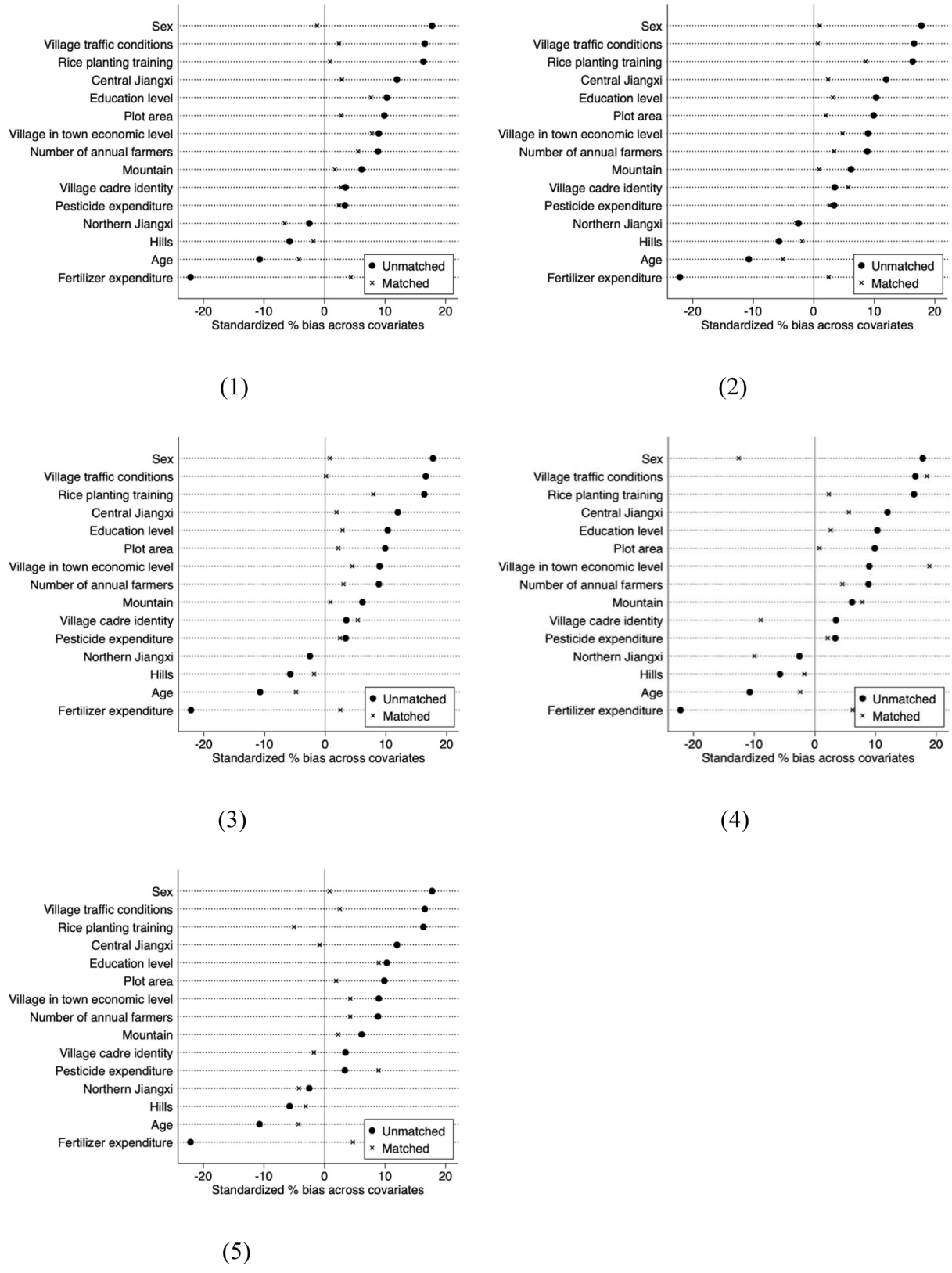

FIGURE 3
Standardized deviation diagram of variables.

a moderate scale of operation through reasonable allocation of production factors. Existing literature indicates that the increase in the scale of farmers' land operation not only does not reduce land productivity, but in most cases, it instead increases it (Fan and Zhou, 2014). From the perspective of the heterogeneity of production input, it is concluded that large-scale operation is more efficient than

TABLE 6 2SLS estimation result of the influence of agricultural socialized services on grain yield per unit area.

Variable	First stage	Stage II
	Agricultural socialization service	Grain yield per unit area
Village-level socialized services	0.268*** (0.053)	
Agricultural socialized service		1.913*** (0.559)
Individual characteristics	Controlled	Controlled
Management characteristics	Controlled	Controlled
Village characteristics	Controlled	Controlled
Constant	1.148** (0.490)	1.834 (1.585)
First stage *F* Test	25.446***	
Observations	893	893
R-squared	0.136	

The *, **, and *** in the upper right corner of the coefficient indicate statistical significance at the level of 10, 5, and 1% respectively, and marginal effect and standard error are reported (in brackets).

TABLE 7 Robustness test results.

Variable	(1)	(2)	(3)
The degree of adoption of agricultural socialized services	0.192*** (0.05)	0.000** (0.00)	0.302*** (0.10)
Individual characteristics	Controlled	Controlled	Controlled
Management characteristics	Controlled	Controlled	Controlled
Village characteristics	Controlled	Controlled	Controlled
Constant	4.605*** (0.72)	4.715*** (0.97)	1.785 (1.43)
Observations	893	893	610
R-squared		0.126	0.162

TABLE 8 Mediation analysis of the relationship between the adoption of agricultural socialized services and grain yield per unit area.

Variable	(1)	(2)	(3)
The degree of adoption of agricultural socialized services	0.077*** (0.01)	0.943*** (0.30)	0.015** (0.01)
Individual characteristics	Controlled	Controlled	Controlled
Management characteristics	Controlled	Controlled	Controlled
Village characteristics	Controlled	Controlled	Controlled
Constant	0.159*** (0.06)	−0.908 (4.45)	0.750*** (0.10)
Observations	893	893	893
R-squared	0.406	0.348	0.036

The *, **, and *** in the upper right corner of the coefficient indicate statistical significance at the level of 10, 5, and 1% respectively, and marginal effect and standard error are reported (in brackets).

small-scale operation (Helfand and Levine, 2004). Hypothesis H3 is thereby validated.

4.4.3 Planting structure

The results are shown in Table 8 (3). At the statistical level of 5%, the adoption degree of agricultural socialized services significantly affects the proportion of rice in agricultural production, with a coefficient of 0.015. This indicates that the adoption of agricultural socialized services by farmers during the production process will affect their planting structure and promote the "grain-oriented" of agricultural production. The "grain-oriented" planting structure is conducive to promoting the intensification of grain production and ensuring that grain output tends to be stable (Yuan et al., 2021). From the perspective of total factor productivity, the research finds that the adjustment of the internal planting structure of grain can promote the high-quality growth of grain (Li et al., 2019). Hypothesis H4 is thereby validated.

TABLE 9 Heterogeneity test results: grain producing county.

Variable	Grain producing county	Non grain producing county
The degree of adoption of agricultural socialized services	0.363*** (0.11)	0.134 (0.10)
Individual characteristics	Controlled	Controlled
Management characteristics	Controlled	Controlled
Village characteristics	Controlled	Controlled
Constant	3.815** (1.77)	5.179*** (1.42)
Observations	483	410
R-squared	0.181	0.053

The *, **, and *** in the upper right corner of the coefficient indicate statistical significance at the level of 10, 5, and 1% respectively, and marginal effect and standard error are reported (in brackets).

TABLE 10 Heterogeneity test results: land fragmentation.

Variable	Low land fragmentation	High land fragmentation
The degree of adoption of agricultural socialized services	0.426*** (0.12)	0.104 (0.10)
Individual characteristics	Controlled	Controlled
Management characteristics	Controlled	Controlled
Village characteristics	Controlled	Controlled
Constant	3.665* (1.87)	2.898** (1.40)
Observations	428	465
R-squared	0.199	0.063

The *, **, and *** in the upper right corner of the coefficient indicate statistical significance at the level of 10, 5, and 1% respectively, and marginal effect and standard error are reported (in brackets).

4.5 Heterogeneity analysis

4.5.1 Regional characteristics

Jiangxi Province's grain production is predominantly concentrated in the Poyang Lake Plain Grain Production Area, the Ganfu Plain Grain Production Area, the Jitai Basin Grain Production Area, and the High-Yield Zone in Western Jiangxi. The "Three Regions and One Zone" collectively accounts for 90.2% of the province's total grain output. Counties within "Three Regions and One Zone" are classified as main grain-producing counties, while others are designated as non-grain-producing counties. The results are shown in Table 9. Under the premise that the variables of individual characteristics, management characteristics, and village characteristics remain unchanged, the adoption of agricultural socialization services in main grain-producing counties has a positive and significant impact on the yield per unit area of rice at the 1% level, while that in non-major grain-producing counties has no significant impact and is negative. The possible reasons are that the policy of preferential agriculture generally prioritizes the main grain-producing counties, where agricultural infrastructure is relatively comprehensive, production scales are larger, and technological levels are more advanced. Adopting agricultural socialized services in these regions effectively leverages their inherent advantages, enhancing crop resilience and increasing grain yield per unit area. In contrast, non-grain-producing counties prioritize secondary and tertiary industries, possess limited agricultural land, and consequently exert minimal impact from agricultural socialized services on food production. Moreover, it may cause resource waste with the increase in adoption.

4.5.2 Farmland characteristics

Land fragmentation is defined as the ratio of the actual cultivated area to the number of cultivated plots. Using 0.067 plots/hm^2 as the classification threshold, the group categorized high land fragmentation is characterized by values $\leq$ 0.067 plots/hm^2, while the group categorized low land fragmentation shows values > 0.067 plots/hm^2. The analytical results are presented in Table 10. Under the premise that the variables of individual characteristics, management characteristics and village characteristics remain unchanged, the adoption of agricultural socialized services in areas with low land fragmentation demonstrates a statistically significant positive impact on rice yield per unit area at the 1% significance level, whereas no significant effect is observed in areas with high land fragmentation. The possible reason is that the high land fragmentation impedes the effective utilization of modern agricultural equipment, increases service commuting time, compromises the quality of agricultural machinery operations, and ultimately constrains grain production. Conversely, the lower degree of land fragmentation means that farmland is relatively concentrated, water irrigation is convenient, there are more favorable production conditions, and operational complexity is reduced. The more significant positive externalities of agricultural land production will make agricultural social services more feasible and economical after adoption, and service organizations can provide services such as farming and seed substitution more efficiently, promoting the improvement of grain yield perunit area.

TABLE 11 Heterogeneity test results: farmer household differentiation.

Variable	Low part-time level	High part-time level	Weak digital ability	Strong digital ability
The degree of adoption of agricultural socialized services	0.251*** (0.09)	0.348** (0.16)	0.266** (0.11)	0.317*** (0.11)
Individual characteristics	Controlled	Controlled	Controlled	Controlled
Management characteristics	Controlled	Controlled	Controlled	Controlled
Village characteristics	Controlled	Controlled	Controlled	Controlled
Constant	2.305* (1.27)	7.101*** (2.31)	4.664*** (1.62)	4.616*** (1.64)
Observations	606	287	409	484
R-squared	0.086	0.219	0.180	0.132

The *, **, and *** in the upper right corner of the coefficient indicate statistical significance at the level of 10, 5, and 1% respectively, and marginal effect and standard error are reported (in brackets).

4.5.3 Farmer household differentiation

The proportion of agricultural income to total household income serves as an indicator of occupational differentiation among farmers. A higher proportion corresponds to a lower degree of part-time farming engagement (Jiang et al., 2024). Whether farmers will use the Internet to search for the needed agricultural production information reflects farmers' digital ability (Chen et al., 2024). The results are shown in Table 11. Under the premise that the variables of individual, management, and village characteristics remain unchanged, adopting agricultural socialization services has a more significant effect on improving grain yield per unit area for farmers with higher part-time employment levels. The possible reason is that farmers with a higher degree of part-time employment spend less time on agricultural production. Compared with those with a lower degree of part-time employment, they rely more on agricultural socialization services to compensate for labor shortages, ensuring grain yield. In contrast, the lower degree of part-time farming farmers mainly depend on agricultural income and predominantly employ manual labor in agricultural production. Furthermore, the adoption of agricultural socialized services by farmers with strong digital ability exerts a more significant impact on grain yield per unit area. Enhancing farmers' digital capabilities facilitates broader information access channels, optimizes resource allocation, and fosters greater trust and cooperation with agricultural service organizations, thus improving grain yield per unit area. In conclusion, the impact of adopting socialized agricultural services on grain yield per unit area exhibits variations across different farmer typologies.

5 Discussion

This study aims to determine whether agricultural social services can be effectively applied to agricultural production to increase the per-unit grain yield under the condition of "low profit" from growing grain for farmers. Therefore, this paper utilizes the micro-survey data of Jiangxi Province and employs the OLS model, propensity score matching method, 2SLS model, and mediating effect model to study and find that in the current agricultural socialized service market, the more agricultural socialized services farmers adopt in the grain production process, the more conducive it is to increase the grain yield per unit area.

When compared to prior research, this study's innovation is primarily evident in the following three aspects: (1) The study examined the impact of the degree of adoption of agricultural social services on farmers' grain yield per unit area. This study grain increase from the grain yield per unit area perspective, which aligns more with the trend of sustainable production in modern agriculture. (2) Using multi-objective utility theory and induced change technology theory, this study explains the influence and mechanism of agricultural socialization service on grain yield per unit area and expands the theoretical understanding between them. (3) Explores the heterogeneity of farmers' adoption of agricultural socialized services on grain yield per unit area under different regions, farmland, and types and clarifies the boundary conditions for farmers' adoption of social services to promote grain yield per unit area.

Based on the empirical test and analysis in this paper, first of all, we find that as the adoption degree increases, the number of farmers decreases, indicating that there are fewer farmers with a relatively high adoption degree of agricultural socialization at present, and the adoption degree has not yet reached saturation. This finding is consistent with the research results of Huan et al. (2022) and Lu et al. (2023). Secondly, agricultural socialized services have a positive effect on increasing the per-unit yield of rice and can play a role in ensuring national food security. This is consistent with most of the conclusions of Picazo-Tadeo and Reig-Martínez (2006), Deng et al. (2020) and Wu et al. (2024), also different from the research of Qiu et al. (2021) and Qu et al. (2022), farmers' investment in agricultural services is conducive to saving production costs and investing more resources in increasing the per-unit yield of grain, which is reflected in the robustness analysis. In the mechanism analysis section, based on the work of Li et al. (2024), Yang and Zhang (2023) and Daohe et al. (2025), the adoption of agricultural social services by farmers will enhance the machinery use of the production process, promote the moderate development of agricultural operation scale, and drive the "grain-oriented" planting structure, thereby achieving an increase in grain yield per unit area. Major grain-producing counties, leveraging their inherent advantages, can maximize the production benefits of agricultural socialization services. Moreover, the concentrated and contiguous land is conducive to mechanized operations and unified management, reducing service costs and improving service convenience. Therefore, farmers in grain-producing counties and low-land fragmentation areas significantly strengthen the promotional effect of agricultural socialization services on grain yield per unit area, which confirms the empirical

results of Qian et al. (2024) and Pan et al. (2020). In addition, the impact of socialized agricultural services on grain yield per unit area varies according to farmer characteristics. Farmers with high part-time employment rates possess relatively higher disposable income, while those with strong digital capabilities have distinct advantages in information acquisition. These two categories of farmers have more significant effects in increasing grain yield per unit area through the adoption of agricultural socialization services, a conclusion supported by the work of Jiang et al. (2024) and Chen et al. (2024). From the perspective of the development of agricultural outsourcing in other developing countries, for example, India, South Africa, etc., the major challenge remains in making the most of limited farmland, which can guarantee the agricultural benefits to local people and their access to land (Azadi et al., 2013; Van dergeten et al., 2016). Against the backdrop that the complex global environment is challenging the international capacity for stable food supply, China's efforts to increase grain yield per unit area through agricultural socialized services and promote sustainable food growth within its limited arable land resources align with the trend of The Times (Lu and Du, 2020; Li et al., 2024). This provides a reference model for other developing countries to increase grain production and contributes a share of Chinese strength to the scientific development of world agriculture.

Overall, this study provides valuable insights into the relationship between rice growers' adoption of agricultural socialized services and grain yield per unit area. However, some limitations should be addressed in future research. Firstly, the research on horizontal expansion and the other two major staple grains (wheat and corn) can provide a more comprehensive understanding of the impact of agricultural socialized services in different agricultural environments. Secondly, incorporating longitudinal data to observe the temporal trend will enhance the robustness of the research results. Finally, expanding the sample to China and countries with similar characteristics is conducive to improving the universality of the agricultural socialized service system.

6 Conclusions and policy recommendations

6.1 Conclusion

This study employs survey data from 893 rice farmers in Jiangxi Province collected in 2023 to construct a benchmark regression model, investigating the impacts of agricultural socialization service on grain yield per unit area and its mechanism. Findings indicate that farmers' adoption of agricultural social services exerts a statistically significant positive effect on grain yield per unit area. This positive relationship remains robust after considering potential sample self-selection bias, reverse causality, omitted variable bias, and rigorous robustness checks. Agricultural socialized services will affect the per-unit grain yield by influencing the use of machinery, the scale of operation and the planting structure. Further, heterogeneity analysis indicates that farmers in main grain-producing counties and low land fragmentation degree areas could significantly strengthen the promotion effect of adopting agricultural socialization service on grain yield per unit area. Additionally, farmers with a higher degree of part-time employment and stronger digital ability adopted agricultural socialization services to increase the grain yield per unit area more significantly.

6.2 Policy recommendations

Based on the research findings of this article, the policy implications are as follows: First of all, regulate the market development of agricultural service industries based on the production demands of farmers, and enhance the accessibility and efficiency of agricultural socialized services. Service providers should formulate clear guidelines and implement accountability systems to prevent unreasonable service price increases and enhance services' ability to promote the organic connection between small-scale farmers and modern agriculture. Secondly, guiding farmers in specialized production and promoting moderate-scale operations is important. Guide farmers to apply modern agricultural production factors and conduct scientific management throughout the process, from tillage and fertilization to harvesting, to enhance the sustainable utilization and protection of cultivated land resources. Encourage farmers with a long-term and stable willingness to engage in farming to expand their operational scale moderately. The practical experience of "consolidating small plots into larger ones" should be systematically summarized to promote the spatial concentration of arable land and improve grain production profitability. Finally, rural infrastructure should be improved, and policy precision and orientation should be strengthened. Pay attention to the differentiation of responses of farmers with different characteristics in different regions. Establish a diversified agricultural socialized service platform that combines online and offline channels, and develop agricultural socialized services based on local conditions and individual needs to maximize their effectiveness. Food security is closely related to human development. The core value of the agricultural service industry lies in creating new agricultural productivity. Governments, farmers and agricultural service industries of all countries must shoulder the responsibility of ensuring food security, jointly commit to the modernization of national agriculture, produce more food from the limited arable land resources, and promote the construction of a more efficient, inclusive and resilient agricultural and food system globally.

Data availability statement

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

Author contributions

LL: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft. JG: Formal analysis, Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing. YP: Data curation, Investigation, Software, Validation, Writing – review & editing. YaL: Investigation, Validation, Writing – review & editing. YiL: Visualization, Writing – review & editing. YT: Supervision, Visualization, Writing – review & editing.

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Conflict of interest

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

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2025.1611236/full#supplementary-material

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